U. S. DEPARTMENT OF COMMERCE
BUREAU OF FISHERIES

PROGRESS IN BIOLOGICAL INQUIRIES 1930

By ELMER HIGGINS

U. S. DEPARTMENT OF COMMERCE
R. P. LAMONT, Secretary
BUREAU OF FISHERIES
HENRY O'MALLEY, Commissioner

PROGRESS IN BIOLOGICAL INQUIRIES 1930

By ELMER HIGGINS

APPENDIX III TO REPORT OF COMMISSIONER OF FISHERIES
FOR THE FISCAL YEAR 1931

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1931

For sale by the Superintendent of Documents, Washington, D. C. - - - Price 20 cents

PUBLICATIONS OF THE BUREAU OF FISHERIES

Administrative Reports.—This series contains the annual report of the commissioner and the four divisional reports; namely, Alaska Fishery and Fur-Seal Industries, Fishery Industries of the United States, Progress in Biological Inquiries, and Propagation and Distribution of Food Fishes. These papers are distributed only as independent octavo pamphlets; however, a general title-page and table of contents for each annual series is distributed for the convenience of those who wish to bind them.

Investigational Reports.—These papers include the results of research in applied science in the fields of biology, technology, economics, and statistics of the fisheries. They are distributed only as octavo pamphlets bearing continuous serial numbers. Volume numbers are assigned for the convenience of those who wish to bind them.

Bulletins.—The papers composing the bulletin are on biological subjects, usually technical, and are issued in royal octavo, with continuous pagination. They are distributed only as separates. A general title-page, table of contents, and index are issued when the volume is complete.

Fishery Circulars.—These papers contain brief popular accounts of investigations having economic importance or general interest and include information of timely significance not requiring more extensive treatment. They are octavo pamphlets with independent serial numbers.

Applications for the above publications should be addressed to the Superintendent of Documents, Government Printing Office, Washington, D. C., who will supply them at advertised prices.

Statistical Bulletins.—Statistical bulletins cover (*a*) statistics of the catch and value of fishery products, gear employed in catching, and related fishery industries, in the various geographical sections of the United States, these being issued for each section periodically; (*b*) statistics of fishery products landed at Boston and Gloucester, Mass., Portland, Me., and Seattle, Wash., by American fishing vessels; halibut landed at North Pacific ports, and cold-storage holdings of fish and fish frozen, these being published monthly; and (*c*) production and value of manufactured products and by-products of the United States and Alaska, this being published annually. These bulletins have independent serial numbers. Those who wish any of them should write direct to the Bureau of Fisheries.

PROGRESS IN BIOLOGICAL INQUIRIES, 1930[1]

By Elmer Higgins, *Chief, Division of Scientific Inquiry*
(With the collaboration of investigators)

CONTENTS

[1]Appendix III to the Report of the U. S. Commissioner of Fisheries for 1931. Approved for publication, July 30, 1931.

INTRODUCTION

Progress in biological investigations during the year 1930 as conducted by the bureau's division of inquiry respecting food fishes, has been most gratifying. According to our present views, the program of scientific research shows a better balance between the theoretical and the practical aspects of fishery science and aquatic biology and a more satisfactory distribution of projects among the various sections of the country and the fishery industries than ever before. There are still many gaps in the program. Many fisheries are threatened by depletion. Means of augmenting the fish supply in many localities must still be devised. Many of the very principles of fishery conservation still await discovery. However, through the adoption of a well-rounded research plan, made possible by the act of May 21, 1930, known as the 5-year construction and maintenance program for the United States Bureau of Fisheries, we are confident that results of practical benefit will accrue to the fishery industries, to the game-fish angler, and to the country at large that many times outweigh the expenditures involved.

Although the functions of the Bureau of Fisheries have been vastly enlarged since its establishment in 1871 by the organization of first, the division of fish culture, then the division of fishery industries, and later, the Alaska division, the division of inquiry still discharges many of the original functions of the old Fish Commission, especially those of prosecuting the necessary inquiries, chiefly biological in character, regarding the occurrence and the extent of declines in the number of food fishes in the coastal and interior waters, of discovering what the causes of such declines may be, and of devising and recommending means of overcoming such declines either by regulatory legislation or by more positive and direct means of augmenting the resource.

The marine fishes of the Atlantic and Pacific coasts support a tremendous food industry. No longer are new fishing grounds being discovered as in former years, but the exploitation of the more productive grounds has increased rapidly during the past decade. Hence, the outstanding problem of these fisheries receiving first attention by the division of inquiry is that of proper husbanding of the supply in order that the resource may be utilized to the fullest extent compatible with its maintenance in a state of maximum productivity. In the North Atlantic area, the fisheries are being critically studied to discover at the earliest moment signs of depletion

from overfishing, and the factors that govern fish reproduction are being examined so that advance information regarding fluctuations in abundance may be made available to the industry. On the Pacific coast inquiries of a similar sort are being prosecuted, and in the Alaska fisheries, the results of such investigations find immediate application in the drafting of fishery regulations imposed by the Federal Government. Fisheries in the interior waters, aside from those in the Great Lakes, are prosecuted primarily for sport and recreation. The tremendous increase in the army of anglers, coupled with industrialization and resulting stream pollution in the eastern half of the country have placed an intolerable strain upon the fish supply; and investigations are, therefore, directed toward the intelligent restocking of depleted waters, toward the perfection of fish cultural methods for such purposes, and toward overcoming the pollution menace. The shellfish resources of our coast line have been an important food resource since earliest times, and recent researches as to their dietary values enhance rather than detract from their importance as a healthful food. Unrestrained harvesting of the natural supply has led to marked depletion in many areas, and the view is rapidly gaining popular acceptance that the adoption of modern methods of farming of oysters, clams, and other mollusks, either by private initiative or through rigid State regulation, is the only practicable means of restoring the productivity of our shellfish beds. The bureau investigations are, therefore, directed to that end with gratifying results that appear to be fully appreciated by the industry. Minor problems of research conducted by the division all tend toward the solution of these practical problems of the fisheries. The period of exploration and description reached its height during the last century and has passed. More modern methods of experimental biological and statistical analysis have taken its place, and fisheries research is rapidly assuming the form and content of an exact science.

In previous reports mention has been made of extensive cooperation in fishery research by States and other institutions. During the past year, cooperation still greater than ever before has been accorded. In addition to the occasional support and encouragement in specific projects such as the furnishing of boats, men, gear, or other services rendered by the various States and which have been continued through the past year, large-scale projects have been assumed by several States on scientific programs, supervised by the bureau's staff. So complete has been the States' confidence in certain undertakings that considerable funds have actually been deposited in the United States Treasury for disbursement on these cooperative projects by bureau investigators. Such cooperation, which is gratefully acknowledged, is in most cases mentioned in connection with the various investigations in the following pages.

Investigators of the division of scientific inquiry have continued to participate in the activities of the North American Council on Fishery Investigations. The seventeenth meeting of this organization was held in Washington on November 6 and 7, 1930. The nations represented were Canada, Newfoundland, France, and the United States. All of these nations have important interests in fisheries of the western North Atlantic and all of them are engaged to a greater

or lesser degree in conducting scientific investigations with a view to developing and conserving the fishery resources. The purpose of the meetings of this organization is to coordinate the program of research of the several nations with respect to high seas fishery problems.

In the membership of the council the United States is represented by Dr. H. B. Bigelow, chairman, Museum of Comparative Zoology, Cambridge, Mass.; by Henry O'Malley, Commissioner, and Elmer Higgins, chief of the division of scientific inquiry, both of the U. S. Bureau of Fisheries. Canada is represented by W. A. Found, Deputy Minister of Fisheries, Ottawa, and Dr. A. G. Huntsman and Prof. J. P. MacMurrich, of the Biological Board of Canada. Newfoundland's representatives were H. B. C. Lake, Minister of Marine and Fisheries, St. Johns, Newfoundland; and Dr. Harold Thompson of the Scottish Fishery Board, stationed for the present at St. Johns. France is represented by Dr. Ed. le Danois, director, Office Scientifique et Technique des Pêches Maritimes, Paris.

A wide range of subjects relating to the practical and scientific problems of the fisheries occupied the attention of the committee during its 2-day session. Reports were received from members of the committee and from a number of investigators attending the session as guests on investigations of the cod, haddock, mackerel, herring, squid, Passamaquoddy power project, ocean currents and temperatures, and fishery statistics. Particularly interesting contributions were made by O. E. Sette and W. C. Herrington, of the North Atlantic staff of the Bureau of Fisheries, who outlined their respective investigations on the mackerel and the haddock.

One of the high lights of the committee's session was Doctor le Danois's exposition of his research in the waters off the coast of Europe and on this side of the Atlantic. Investigations of the water on the other side disclosed that mid-Atlantic water pushes to the northward every summer and recedes in the winter, and that this movement is particularly pronounced in certain years. Every 18 years there seems to be an exceptional movement of this warm water. It appears that in the years of this movement of tropic waters northward there is impaired success of the codfishery in its southern range on the Grand Banks, forcing the fishermen to fish the waters northward in order to make good catches. It has been because of the movements of the fish northward in the past two or three years that fishermen from Europe have come to Greenland in unprecedented numbers.

While heretofore Newfoundland has been able to contribute little aid to scientific research in the North Atlantic region, it is at the present time embarking on such investigations on a considerable scale. Dr. Harold Thompson, well-known fishery investigator of the Scottish Fishery Board, has just completed a preliminary survey of the requirements of a program of practical and scientific fishery investigations in Newfoundland, and is planning a sound program of study employing the facilities of a laboratory ashore and a research trawler at sea from funds to be furnished jointly by the Newfoundland Government and the British Empire Marketing Board. Through the efforts of the North American Council, Doctor Thompson's proposed studies will be closely correlated with those

conducted by the French authorities on the Grand Banks and by the other Governments.

Much interest was shown in the program of investigation of the newly established Woods Hole Oceanographic Institution, of which the chairman of the council, Doctor Bigelow, is director. The committee urged the importance of obtaining more exact knowledge of ocean currents and temperatures in the North Atlantic region, because of the direct effects of such phenomena upon the fish life. It formally requested that institution to undertake at once a study of the results already obtained from the many drift-bottle experiments conducted by the several countries, and to correlate the findings bearing on the broader aspects of ocean circulation.

The committee also gave further consideration to the probable effects on the fisheries of the damming of Passamaquoddy Bay for hydroelectric power and reiterated its previous stand as to the importance of not only settling the controversial problems but of obtaining a proper understanding of the fishery situation of the region in general.

During the year 15 scientific or administrative reports were published under the supervision of the division or as a result of investigations of its staff. The list of papers follows:

COKER, ROBERT E.
Studies of common fishes of the Mississippi River at Keokuk. Bulletin, Vol. XLV, 1929, 87 pp., 30 illus. Document No. 1072.

DAVIS, H. S., and A. H. WIEBE.
Experiments in the culture of the black bass and other pond fish. Appendix IX, Report of Commissioner, 1930, 29 pp., 6 illus. Document No. 1085.

DAVIS, H. S., and R. F. LORD, Jr.
Experiments with meat and meat substitutes as trout foods. Appendix VII, Report of Commissioner, 1930, 27 pp., 11 illus. Document No. 1079.

FEDERIGHI, HENRY.
Control of the common oyster drill. Economic Circular No. 70, 7 pp., 5 illus.

GALTSOFF, PAUL S.
Destruction of oyster bottoms in Mobile Bay by the flood of 1929. Appendix XI, Report of Commissioner, 1929, 20 pp., 3 illus. Document No. 1069.

GALTSOFF, PAUL S., and R. H. LUCE.
Oyster investigations in Georgia. Appendix V, Report of Commissioner, 1930, 42 pp., 23 illus. Document No. 1077.

GALSTOFF, PAUL S., H. F., PRYTHERCH, and H. C. MCMILLIN.
An experimental study in production and collection of seed oysters. Bulletin, Vol. XLVI, 1930, 69 pp., 40 illus. Document No. 1088.

HIGGINS, ELMER.
Progress in biological inquiries, 1928, including extracts from the proceedings of the divisional conference January 2 to 5, 1929. Appendix X. Report of Commissioner, 1929, 115 pp. Document No. 1068.

HILDEBRAND, SAMUEL F.
The Bureau of Fisheries and its biological station at Beaufort, N. C. Economic Circular No. 72, 14 pp., 9 illus.

PRYTHERCH, HERBERT F.
Improved methods for the collection of seed oysters. Appendix IV, Report of Commissioner, 1930, 15 pp., 9 illus. Document No. 1076.

ROUNSEFELL, GEORGE A.
Contribution to the biology of the Pacific herring, *Clupea pallasii*, and the condition of the fishery in Alaska. Bulletin, Vol. XLV, 1929, 96 pp., 53 illus. Document No. 1080.

SCHROEDER, WILLIAM C.
Migrations and other phases in the life history of the cod off southern New England. Bulletin, Vol. XLVI, 1930, 138 pp., 33 illus. Document No. 1081.

THOMPSON, SETON H.
Salmon tagging in Alaska, 1929. Bulletin, Vol. XLVI, 1930, 21 pp., 6 illus. Document No. 1084.
WIEBE, A. H.
Investigations on plankton production in fish ponds. Bulletin, Vol. XLVI, 1930, 42 pp., 6 illus. Document No. 1082.

In addition to these, the following papers were published by the staff during the past year in other than the bureau's series:

CRAIG, JOSEPH A.
An analysis of the catch statistics of the striped bass (*Roccus lineatus*) fishery of California. Fish Bulletin, No. 24, Division of Fish and Game of California, pp. 1–41. Sacramento.
DAVIDSON, F. A.
Graphical and mathematical treatments in growth studies. Contributions to Marine Biology. Stanford University Press.
Interpretations of the curve of normal growth. Science, Vol. LXXII, No. 1861, p. 226. Lancaster, Pa.
DAVIS, H. S.
Some principles of bass culture. Transactions, American Fisheries Society, Vol. LX, pp. 48–52. Hartford.
Investigations in pond-fish culture at the Fairport Biological Station. Transactions, American Fisheries Society, Vol. LIX, pp. 86–93. Hartford.
DAVIS, H. S., and R. F. LORD.
The use of substitutes for fresh meat in the diet of trout. Transactions American Fisheries Society, Vol. LIX, pp. 160–167. Hartford.
ELLIS, M. M.
Artificial propagation of fresh-water mussels. Transactions, American Fisheries Society, Vol. LIX, pp. 217–223. Hartford.
GALTSOFF, PAUL S.
The rôle of chemical stimulation in the spawning reactions of *Ostrea virginica* and *Ostrea gigas*. Proceedings, National Academy of Science, Vol. XVI, No. 9, pp. 555–559. Easton, Pa.
The fecundity of the oyster. Science, Vol. LXXII, pp. 97–98. Lancaster, Pa.
HIGGINS, ELMER.
Conservation of the fisheries. *In* Conservation of Our Natural Resources, by Van Hise, Hevemeyer, et al. Chapter V, pp. 466–504. The MacMillan Co., New York.
What is science doing for the fisheries? Fishing Gazette, Annual Review Number, June 15, 1930, pp. 63–70. New York.
HILDEBRAND, S. F.
Notes on a collection of fishes from Costa Rica. Copeia, No. 1, pp. 1–9. Ann Arbor, Mich.
Duplicity and other abnormalities in diamond-back terrapins. Journal, Elisha Mitchell Scientific Society, vol. 46, No. 1, November, 1930, pp. 41–53, 4 pls. Chapel Hill, N. C.
LORD, R. F.
Rearing a brood stock of black spotted trout. Transactions, American Fisheries Society, Vol. LX, pp. 164–166. Hartford.
PALMER, LOUISE.
Investigation for the control and elimination of starfish on oyster beds The Biological Laboratory, Vol. II, No. 3. Cold Spring Harbor, N. Y.
ROUNSEFELL, GEORGE A.
The existence and causes of dominant year classes in the Alaska herring. Contributions to Marine Biology, pp. 260–270, 5 illus. Stanford University Press.
SCHROEDER, WILLIAM C.
Habits of southern New England Cod. Fishing Gazette, March, 1930. New York.
A record of *Polyprion americanus* (Block and Schneider) from the northwestern Atlantic. Copeia, No. 2. Ann Arbor, Mich.
SETTE, O. E.
Mackerel will be plentiful during 1930. Fishing Gazette, April, 1930. New York.
A series of articles entitled "Progress of the mackerel fishery." Fishing Gazette, June, 1930–December, 1930, 7 monthly editions. New York.

SURBER, E. W.
A quantitative method of studying the food of small fishes and its possibilities. Transactions, American Fisheries Society, Vol. LX, pp. 158–163. Hartford.
A method of quantitative bottom fauna and facultative plankton study employed in a year's study of slough biology. Transactions, American Fisheries Society, Vol. LX, pp. 187–198. Hartford.
The utilization of sloughs in the Upper Mississippi Wild Life and Fish Refuge as fish ponds. Transactions, American Fisheries Society, Vol. LIX, pp. 106–113. Hartford.
TAFT, A. C.
The growth of salmon. Contributions to Marine Biology, Chapter XXI, pp. 253–259. Stanford University Press.
VAN OOSTEN, JOHN.
Some fisheries problems of the Great Lakes. Transactions, American Fisheries Society, Vol. LIX, pp. 63–85. Hartford.
The disappearance of the Lake Erie cisco—A preliminary report. Transactions, American Fisheries Society, Vol. LX, pp. 204–214. Hartford.
WIEBE, A. H.
Notes on the exposure of young fishes to varying concentrations of arsenic. Transactions, American Fisheries Society, Vol. LX, pp. 270–278. Hartford.
The effects of various fertilizers on plankton production. Transactions, American Fisheries Society, Vol. LIX, pp. 94–105. Hartford.

The following progress reports covering the more important investigations conducted by the division during the calendar year 1930 were prepared in the main by the investigators in charge of the various projects.

NORTH AND MIDDLE ATLANTIC FISHERY INVESTIGATIONS

The provision of additional funds during the past year has made it possible to expand the scientific studies to include practically all of the more important sea fisheries of this region. In order of their commercial importance the fisheries now being investigated are: Haddock, cod, mackerel, flounder, and the group of species (squeteague, scup, butterfish, etc.), comprising the bulk of the commercial catch alongshore from southern New England to Delaware Bay. The objective is to understand the causes of changes in the fish population, their implications as to the future of the industry, and to be in a position to recommend corrective measures if such should prove necessary.

So little is known about the biological economy of the sea, and so imperfect are the records of man's inroads on its edible stores that the task becomes a group research problem of almost incredible complexity. It involves such diverse inquiries as the determination of the feeding habits of minute newly hatched fish larvæ and the appraisal of the efficiency of various types of commercial fishing gear. The main approaches toward a solution are to derive a measure of changes in abundance from the records of commercial catches through a series of years, to examine samples of the fish population for clues given by the age of the individuals as to the rate of replacement in relation to the loss from natural mortality as well as the toll taken by man, to study the drift of eggs and larvæ for information on the sources of recruits to the fishing grounds, to mark fish with tags to see whether their movements from one ground to another may be the cause of changes in yield, and to study the effects of oceanic conditions on the nurture, movements, and even survival of the species under consideration.

To provide for the cooperation necessary in such a many-sided task, the scientific staff has been centralized at Cambridge, Mass., where laboratory and library facilities have been generously provided by the Museum of Comparative Zoology. This not only has the advantage of coordinating the work, but also makes it possible to consult readily members of the zoological, physiological, physical, and chemical departments of Harvard University, when problems arise requiring special knowledge in particular fields. Especially valuable has been the constant advice of Prof. Henry B. Bigelow, curator of oceanography, whose extensive experience and intimate knowledge of oceanic phenomena off our Atlantic coast has always been available to guide the course of our studies.

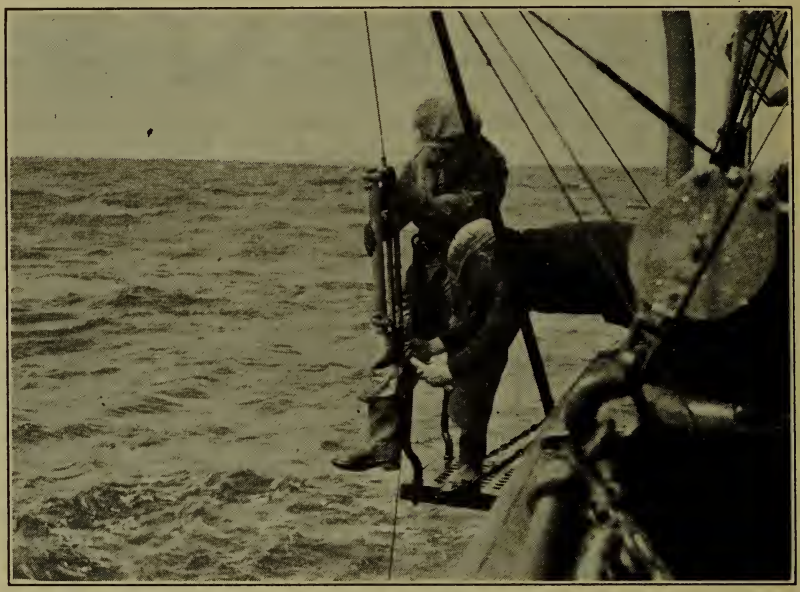

FIGURE 1.—Oceanographic work aboard the *Albatross II*. Attaching a messenger to a Green-Bigelow water bottle used to secure a series of water samples and temperature at various depths

Equally gratifying have been the results of cooperation with the Bingham Oceanographic Foundation of Yale University. Prof. A. E. Parr, curator of that institution, has kindly given generously of his time to supervise the studies on the spawning of food fishes and growth of their young in the Delaware Bay region, and his findings already have provided valuable links in the chain of circumstances governing the maintenance of the squeteague fishery.

The progress made during 1930 on the various projects included in the research work on the North and Middle Atlantic coast is summarized in the following sections.

OCEANOGRAPHIC STUDIES

Perhaps the outstanding result of fishery investigations both in this country and abroad during the last two decades has been the

recognition of the fact that many of the changes in abundance of fishes which cause the ups and downs in commercial yields are largely due to variations in the reproductive success in different years. It appears that conditions in certain years are favorable to the survival of the spawning product of certain species; other years'

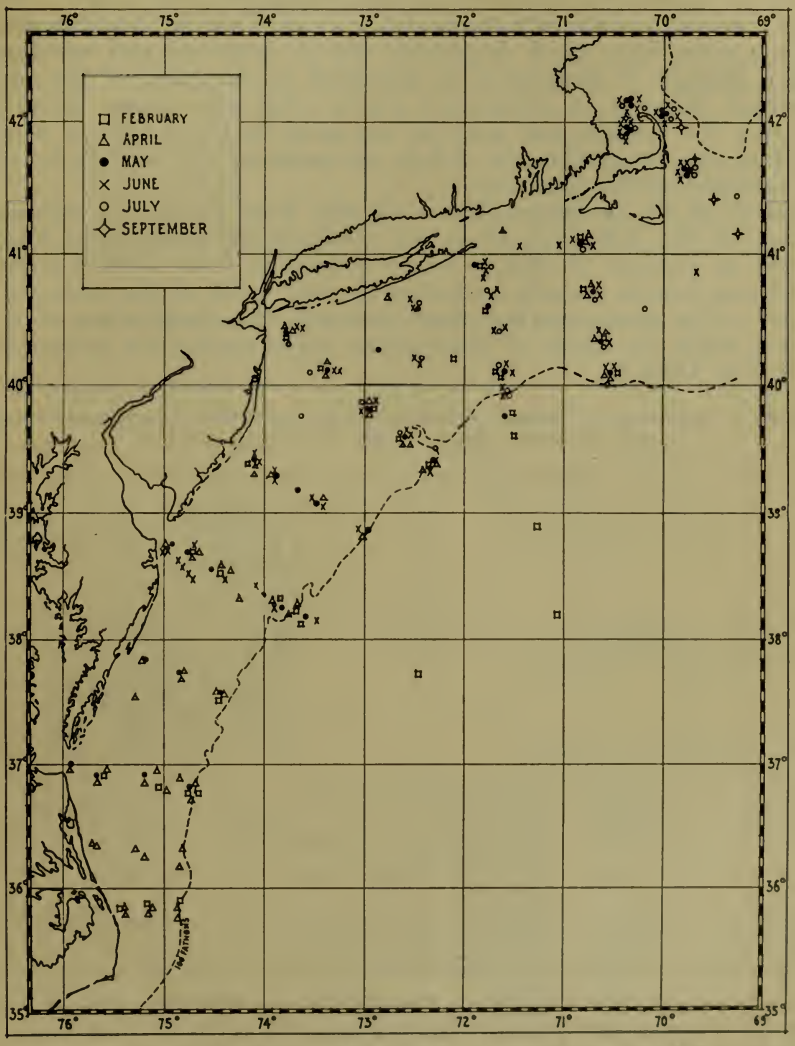

FIGURE 2.—Chart of the Atlantic coast of the United States from Cape Cod to Cape Hatteras, showing the oceanographic stations of the *Albatross II* during 1930

conditions may result in virtually total mortality of the young which that year might have contributed to the stock. These successes or failures leave their impress on the population so that the yield of the commercial fishery in subsequent years will be large or small depending on whether the year classes have to a large degree survived or have to a large degree perished.

The prevalence of this phenomenon in the sea fisheries makes it important to examine the conditions that may be responsible for the survival of year classes. To this end our investigations on fishes proper have been accompanied by studies of oceanographic conditions in so far as the limited means at our disposal would permit. Results of such studies can not be forthcoming in a short time. They involve continuous observations over a series of enough years to establish a norm from which departures may be measured and correlated with changes in abundance as measured by the yield of the commercial fisheries in subsequent years. For this reason progress during the current year must be measured by the degree to which it lays the foundation for future advancement, as well as by the immediate results obtained.

Most of the oceanographic work was done during the repeated visits of the *Albatross II* to the mackerel-spawning areas which cover an expanse of offshore waters extending from North Carolina to Massachusetts, usually including the full width of the continental shelf. The accompanying chart indicates the distribution of stations, while the kinds of observations made during the cruises are listed in Table 1.

TABLE 1.—*Summary of offshore oceanographical work done in conjunction with cod, mackerel, and shore-fish investigations, 1930*

Date	Station numbers [1]	General locality	Number of stations occupied	Temperature and salinity observations		Collections made					
				Serials, surface to bottom	Surface only	Zoo-plankton surface horizontal	Phyto-plankton surface horizontal	Zoo-plankton oblique	Zoo-plankton serial horizontal [2]	35-foot otter trawl	Welsh trawl
Feb. 5–13	20618–20651	No Mans Land, Mass., to Bodie Island Light, N. C.	34	34	----	1	20	22	----	15	7
Apr. 3–11	20652–20678	Do	27	27	----	10	25	18	----	12	1
Apr. 23–May 1	20679–20715	Cape Cod Bay, Mass., to Bodie Island Light, N. C.	37	36	1	----	36	36	----	15	----
May 12–23	20716–20760	Cape Cod Bay, Mass., to Cape Henry, Va.	45	42	3	34	19	38	1	8	9
June 6–14	20761–20791	Cape Cod Bay, Mass., to Cape May, N. J.	31	31	----	24	1	28	----	6	10
June 17–18	20792–20795	Cape Cod Bay, Mass., and offing of Cape Cod.	4	4	----	3	----	3	1	1	----
June 23–July 1	20796–20831	Cape Cod Bay, Mass., to Cape May, N. J.	36	35	1	35	----	35	1	5	8
July 7–8	20832–20835	Cape Cod Bay, Mass., and offing of Cape Cod.	4	4	----	4	----	4	----	----	----
July 10–14	20836–20853	Nantucket Shoals to Barnegat, N. J.	18	18	----	18	----	18	----	16	1
July 16–18	20854–20858	Cape Cod Bay, Mass., and offing of Cape Cod.	5	5	----	3	----	3	2	2	----
Aug. 1–Sept. 9	20859–20869	Miscellaneous cod tagging trips in Gulf of Maine.	11	3	2	----	----	----	----	9	----
Sept. 15–17	20870–20874	Cape Cod Bay, Mass., and offing of Cape Cod.	5	5	----	----	----	----	5	----	----
Oct. 17–23	20875, 20876	Offing of Cape Cod, Mass.	2	1	----	----	----	----	1	1	----
		Total	259	245	7	132	101	205	11	90	31

[1] Albatross series.

[2] 2 series of hauls, 1 in daylight and 1 at night, were taken at each station. Each series consisted of horizontal tows at 5 or more levels.

From analysis of these data we shall have successive pictures of hydrographic conditions and of the horizontal distribution of plankton during the months of February, April, May, June, and July, the months that probably are most significant in the life history of the principal food fishes of that region.

In addition to the regular plankton collections, which are intended to show only the horizontal distribution, series of hauls have been taken at different levels at 11 stations to determine vertical distribution. The data from these series are expected to facilitate the interpretation of peculiarities in the horizontal distribution and to throw light on the ecology of the plankton community.

Surface drift bottles were released in eight series, a total of 953 bottles. Returns have been so few and their paths so divergent that interpretation of drifts is difficult. It is possible that further light may be cast on the question by additional returns during the coming year.

TABLE 2.—*Record of releases and returns of drift bottles in 1930*

Releases			Returns	
Date	Locality	Number	Number	Remarks
Feb. 6, 12, and 13.	South of Montauk Point, Long Island, N. Y.	249	1	Westerly.
Feb. 7 and 8	Southeast of New York, N. Y.	180	2	1 northeasterly to Long Island, N. Y.; and 1 to Azores.
Apr. 5	Southeast of Cape Henlopen, Del.	114		
Apr. 6	East-southeast of Cape Henry, Va.	54		
May 14	East-southeast of New York	122	11	NE.-SW. on shores of Long Island, N. Y., and New Jersey.
May 16	Southeast of New York	146	2	Northeasterly to Long Island, N. Y., and Marthas Vineyard, Mass.
May 17	Southeast of Atlantic City, N. J.	32		
June 25	South of No Mans Land, Mass.	56	13	9 north and east to Cape Cod, Nantucket, and Marthas Vineyard, Mass.; 4 northwest to Rhode Island and Long Island, N. Y., shores.
Totals		953	29	3 per cent returned.

COD

The initial step in the study of the codfishery has been the determination of the natural divisions of the cod population. An understanding of a fishery obviously requires knowledge as to whether each locality supports a distinct stock or whether the fish of various localities mix freely. The changes in abundance and the effects of fishing must be interpreted differently depending on which of the two conditions exists. The method of wholesale tagging of adult cod has been efficacious not only in determining the movements of the fish but also has provided a wealth of material on life history and kindred subjects.

During 1930 the cod investigations were continued by William C. Schroeder. Marking experiments, which included the tagging of such haddock and pollock as were caught along with the cod, were made in the following localities:

(*a*) Off Mount Desert, Me., April 25–May 2; July 16–23; and October 4–10.

(*b*) In the offshore waters, including Browns Bank, Georges Bank, Cashes Ledge, and Platts Bank, August 2–7, and September 4–9.

(*c*) On Nantucket Shoals, August 18–21, and October 18–22.

TABLE 3.—*A summary of the fish tagged from 1923 to 1930*

BY SPECIES

	1923–1928 [1]	1929	1930	Total
Number of cod tagged	39,496	1,169	3,415	44,080
Number of pollock tagged	4,799	13	157	4,969
Number of haddock tagged	10,620	134	371	11,125
Total	54,915	1,316	3,943	60,174

BY LOCALITIES

Browns Bank and vicinity	2,113		210	2,323
Georges Bank	2,002		8	2,010
New Hampshire and Maine	19,581		3,426	23,007
Massachusetts, north of Cape Cod	645		12	657
Massachusetts, south of Cape Cod	29,857	848	287	30,992
New York and New Jersey	717	468		1,185
Total	54,915	1,316	3,943	60,174

[1] For more details of the fish tagged from 1923–1928 see Report of the Commissioner for 1928, pp. 631–632.

TABLE 4.—*A summary of the number of cod, pollock, and haddock tagged and recaptured during the years 1923–1930, inclusive*

	Tagged	Recaptured	Per cent
Cod	44,080	2,937	6.8
Pollock	4,969	104	2.1
Haddock	11,125	197	1.8
Total	60,174	3,238	

Much the same results were shown by the recapture records of tagged cod during 1930 as in preceding years. Up to the present time tag returns as high as 35 per cent have been reported for certain lots of cod tagged near shore on grounds often fished; while offshore, on grounds less frequently visited, they have been as low as 1 per cent. While fishing intensity has much to do with this disparity in the numbers of fish recaptured, other things, such as the physical conditions under which the fish were caught at the time of tagging, the security of attachment of the tag, the season of the year, and whether the marked fish belonged to a school that remained localized for some time or was on the point of migrating, have much to do with the percentage subsequently recaught.

Alongshore within the Gulf of Maine to the northward of Cape Cod marking experiments have shown that a good part of the stock of cod present at any given time remains localized for a year or more, that small numbers migrate eastward to Nova Scotia, and that to the northward of Cape Ann only stragglers move southward. These shore waters constitute an important cod nursery for they support a large number of 1, 2, and 3 year old fish.

To the southward of Cape Cod the fall migration of cod from the Nantucket Shoals region into the coastal waters between Rhode Island and North Carolina and the return spring migration northward and eastward has been commented upon from time to time during the past few years. A report dealing with this was published by the bureau during the year.

More information is needed about the cod living on the extensive offshore grounds in the Gulf of Maine before their habits can be determined with any degree of certainty. Results so far have indicated that the Browns Bank cod tend to migrate northward and eastward more than to the southward, that few of them go westward, and that many of the fish may remain on the bank from one year to the next. Some Georges Bank cod migrate to Browns Bank and beyond, across the deep intervening channel, while some move to Nantucket Shoals and the wintering grounds to the westward; but it is probable that the greater part of the vast stock of cod on Georges does not leave the bank.

The capture of large numbers of juvenile cod, about 1 to 2 inches long, on the cod's southern wintering ground to the westward of Rhode Island is noteworthy, as there are no previous records of this sort. These fish were taken between the offing of New York City and the offing of Chesapeake Bay on hydrographic cruises made by the *Albatross II* April 3–12 and April 23–May 1, 1930. Of particular interest was the catch of 360 young, 1 to 2 inches in length, off Little Egg Inlet on April 10, in 12 fathoms, with a 35-foot shrimp trawl having a cod-end lined with bobbinet. Whether these young survive and later migrate eastward, thus replenishing the stock of cod in New England waters, is an important problem for future study. Thus far the indications are either that there is a heavy mortality among these juveniles or that they leave the New York-Virginia waters before summer, for none has been reported there at that season.

Data on the haddock, collected incidentally during the cod investigations from 1923 to 1928, were turned over to Dr. A. W. H. Needler, of the Biological Board of Canada, who made extensive use of them in a report dealing with haddock migrations and populations published during the year.

HADDOCK

The haddock fishery of the western North Atlantic has undergone a tremendous expansion in recent years, with an increase in the landdings from approximately 60,000,000 pounds in 1915 to about 190,000,000 pounds in 1930. This expansion largely has been due to the development of the trade in filleted haddock and has been made possible through the growth of the otter-trawl fleet. In 1915 this fleet consisted of 11 steam trawlers; in 1930 it had increased to approximately 130 large and medium sized trawlers, with many smaller vessels.

In 1930 the appropriations for scientific inquiry were increased to provide for a comprehensive investigation of the haddock fishery for the purpose of obtaining an understanding of the biology of the species in relation to the fishery and of ascertaining the effect of the present extensive exploitation on the haddock population. Work

began in August, 1930, when William C. Herrington, formerly on the research staff of the International Fisheries Commission, was employed to direct the investigation. He is being assisted by Edward W. Bailey and John R. Webster.

After an extensive preliminary survey of the fishery and literature, the following general lines of procedure were decided upon:

(1) Statistics. (*a*) Determination of the relative changes in abundance of haddock on the different banks from year to year by means of an analysis of present and past boat-catch records. (*b*) Collection of more detailed records for future analysis of abundance and fishing intensity.

(2) Population studies. (*a*) Investigation of the causes of fluctuations in abundance which may appear. This will be done through a study of dominant year-classes and the effects of the fishery on the survival of any year-class. (*b*) Determination of the probable effects of the destruction of undersized haddock, caused by the otter-trawl nets, on the future productivity of the banks and the possibility of partially or entirely eliminating it by changes in the size or shape of the mesh or by other changes in the nets.

(3) Study of migration and its effect on the haddock populations of the various fishing banks by means of marking experiments.

(4) Plankton and hydrographic studies. Determination of the extent to which the haddock grounds are interdependent for their supply of young fish. This will be done by collecting plankton and hydrographic data and by the study of the development and drift of the eggs and larvæ.

Each section of the work outlined is an integral part of the general program, which has for its object an understanding of the changes taking place in the haddock population and the causes of these changes. The ultimate objective toward which this program is directed is the determination of the maximum productivity of the fishery and the means by which it may be maintained.

FLOUNDERS

A limited amount of the increased appropriations for work on North Atlantic fishes is available for a study of the flounder fishery. The principal commercial species is the winter flounder or blackback, *Pseudopleuronectes americanus*, and attention will be given to that species mainly.

During recent years there has been a rapid increase in the exploitation of this resource and doubt has been voiced as to the ability of the species to stand the additional strain imposed by the numerous flounder draggers now operating in the waters off the New England coast. Some are of the opinion that the inshore waters have been depleted and fishermen are being forced to go increasing distances offshore to get their fares. Public appreciation of the seriousness of the situation has been evidenced by the closure by Massachusetts State law, of Cape Cod Bay, to flounder draggers from April 1 to September 30.

The most urgent steps to be taken to arrive at the facts of the situation are the establishment of a more effective system of catch records that will reflect the changes in abundance in various locali-

ties; the study of the migrations, in the hope of establishing whether young flounders move out from the inshore grounds to populate the offshore banks; and the discovery of the source of the flounders that concentrate in estuaries and on inshore shoals for the purpose of spawning.

A tag similar to the mark used on the plaice in European tagging experiments has been attached to flounders held in captivity and appears to be well suited to the purpose. Arrangements have been made for the manufacture of a sufficient supply for an extensive field trial to be undertaken early in 1931.

MACKEREL

Investigations of the mackerel fishery during 1930 may be considered in two parts: (1) Observations of the commercial fishery; (2) observations on the success of spawning and survival of the young larvæ.

As in previous years the data on the commercial fishery collected at the principal landing ports have been studied from the point of view of the relative abundance of the mackerel on the various fishing grounds, as compared with previous years, and the relative numerical importance of the several year classes in the mackerel population. The work continued under the supervision of O. E. Sette. Field observations were made by Frank E. Firth at New York in May and June, and at Boston from June to December; by Robert A. Goffin at Cape May, N. J., during April; by William C. Neville at Newport during May; and by various field assistants engaged primarily in the collection of data on the pound-net fisheries of the Middle Atlantic region throughout the fishing season.

Altogether, information was secured as to date, locality, and quantity of 1,863 out of the total of 3,175 fares landed by the offshore fleet. Samples from about 1,500 fares were measured. These, together with 5,652 mackerel measured by pound-net observers, make a total of over 40,715 length measurements for the season. Scale samples were taken from 930 mackerel. A considerable number of vessel captains have continued to cooperate by the keeping of detailed log-book records of their fishing activities.

A final analysis has not been completed, but according to preliminary studies of the data, it appears that 3-year classes were the chief contributors to the commercial catch of 1930. The class of 1923 (including a small percentage of older fish) furnished about 25,000,000 pounds; the class of 1928 furnished 12,000,000 pounds; and the class of 1929 furnished 6,500,000 pounds out of the total catch of 43,500,000 pounds.

The brood of 1923 has now been in the fishery for six years, and during this time it has made up the bulk of the yield. Its diminution in numerical strength has been very gradual. The approximate number of mackerel of this brood in the purse-seine catch in each successive year beginning with 1925, was 19, 24, 20, 14, 11, and 10 millions, respectively. This does not necessarily mean that the relative abundance was exactly as indicated by the above figures for the fishing effort has not been exactly equal during this period; but we believe that they do express the abundance in an approximate

fashion, and indicate that mortality rate is very low once a brood has passed its second year.

Broods which should have been produced in the years 1924 to 1927 have been practically nonexistent. To be sure, the 1927 brood furnished over a million pounds in 1928 and somewhat less in 1929; but in the main, these year classes failed to produce enough survivors of commercial size to be significant in the catch.

The 1928 class furnished 22,000,000 pounds of mackerel in 1929 and 12,000,000 pounds in 1930. A year ago it appeared that the 1928 class was numerically superior to the 1923 class for it furnished nearly five times as much fish in its second year as did the 1923 class when it was of the same age. But the smaller catch of this brood in 1930 calls for a more modest estimate of its size; unless fish of this brood reappear in unexpectedly large numbers in the future. At any rate, it is the most important contingent that has joined the stock since 1923.

It is too early to judge the importance of the 1929 class. The 6,000,000 pounds caught in 1930 indicate the advent of a brood of some importance but the quantity of mackerel caught in the second year of life seems not to be a very good index of their numerical abundance, and judgment must await next year's fishery.

It is obvious from the above observations that the production of a numerically rich year class is an occurrence that takes place only at intervals of several years; but when a large brood is once established, it is a dominant feature of the fishery through at least six years, perhaps more.

An understanding of the conditions which in one year may produce a rich class and in another may cause virtually complete mortality of the current brood is important, both to the understanding of the fishery as a resource to be conserved and for the practical purpose of making more accurate predictions of the abundance of mackerel. For this purpose the *Albatross II* made six cruises to the mackerel spawning grounds during the period from April 3 to July 18. Data were collected to afford a roughly quantitative estimate of the natural production of mackerel eggs and of the survival of the larvæ, together with such observations on the temperature, salinity, and plankton constituents as might be expected to furnish a clue to the factors controlling the success or nonsuccess of the year class.

Later in the season, several short cruises to the mackerel grounds in the offing of Cape Cod were devoted primarily to the collection of data on the vertical distribution of plankton and its possible effect on the availability of mackerel to the commercial fishery.

In accordance with the bureau's policy of making results of its work available to the public as soon as possible, the information on the year class composition of the catch during 1929 was summarized and its implications as to the effect on the fishery during the ensuing season was outlined in articles submitted to fishery trade journals for publication. The weight of evidence indicated a level of abundance that was likely to furnish a catch of about 60,000,000 pounds, provided the intensity of fishing remained practically the same. The total actually realized was 43,500,000 pounds or 27 per cent less than the predicted amount. The discrepancy consisted almost entirely of

failure of the 1928 brood to reappear in the abundance indicated by the unusually large catch (for fish of its age) in the previous year. This emphasizes the need for a more accurate method of determining the abundance of a brood while it is still at an early age. The survey of survival of larvæ on spawning grounds provided by the oceanographic work of the *Albatross II* may help to fill this need, as data on more seasons accumulate.

NEW ENGLAND SMELT

Since the publication of The Smelts (Bureau of Fisheries Document No. 1015) in 1927, Dr. W. C. Kendall has been intermittently engaged in a study of various problems pertaining to those fish. Early in the summer of 1929 he was detailed to accompany MacMillan on an expedition to Baffin Land, which again interrupted the work on the smelts. Following his return from the north, unavoidable circumstances prevented resumption of the study except for occasional brief periods of work on the manuscript which has now reached its final stage. The manuscript comprises three major sections: (1) History of the classification of the smelts and an analytical discussion of the different nominal species and their variants of the genus *Osmerus;* (2) analysis of the data pertaining to the relationship of the smelts of eastern North America; (3) life histories of the smelts based on scale reading and sizes of the fish.

TROUT AND CHARRS

Another study, begun years ago by Doctor Kendall and continued interruptedly to the present time, pertains to the charrs of which the so-called eastern brook trout is the best known example. One problem connected with the latter species is that of the relationship of the "salter" or "sea-run" trout to the brook trout. While a difference of habit has been noted, no difference of structure has been discerned.

The "salter" is a *fontinalis* type of trout in which the habit of passing a considerable part of the year in salt water has become fixed. In spring or early summer it appears in tidal creeks and fresh water sections thereof apparently in pursuit of food. In certain streams of Maine where they are now far from as abundant as they used to be, their appearance has been observed to be concurrent with the appearance of the translucent stage of young eels, known as "elvers," with which they have often been found to be gorged.

This "sea-run" habit is more pronounced or at least more conspicuous, perhaps from great abundance of fish, in Canadian and Newfoundland waters. It would almost seem that the habit is a hereditary trait not shared in by all of the species, and that the salters may be regarded as a "physiological race."

ATLANTIC AND LANDLOCKED SALMON

Another piece of work, by Doctor Kendall, like that pertaining to the smelts, has suffered from protracted interruptions. The work referred to is the preparation of a "Memoir" on the Atlantic and landlocked salmons to be published as Part II of the Salmonidæ

of New England, by the Boston Society of Natural History. Part I comprised the trouts or charrs of New England, published in 1914. During the year the section of Part II pertaining to the Atlantic salmon was completed and has been submitted to the Boston Society and the section pertaining to landlocked salmon is soon to follow.

The topics covered by the "Memoir" comprise about every phase of the natural history of the salmons, with a history of New England salmon rivers and original landlocked salmon lakes. The natural distribution of the fish in North America is restricted to a comparatively few localities comprised in a wide area. While it has received much fish-cultural attention, its fish-cultural distribution has been ill-considered and its "conservation" recklessly administered. The author discusses to some length the subject of restoring of natural salmon lakes that have apparently deteriorated in quantity, quality, and size of fish. A reduction in quantity is usually easily accounted for. While the causes of deterioration in quality or size of the fish may be somewhat more obscure, there are usually associated conditions which indicate the probable causes. However, the author regards the popular idea, that such deterioration is due to inbreeding, as an absurd fallacy. Also that the introduction of "new blood" in the form of a smaller race of salmon or of "Canadian sea salmon" is equally fallacious.

SHORE FISHERIES OF THE MIDDLE ATLANTIC STATES

The statistical canvass of 1926 showed that yields of several of the more important shore fisheries were below normal in New York and New Jersey. An investigation of the causes of this decline was begun in 1927 and has been continued under the direction of R. A. Nesbit.

In order to understand what changes in yield have occurred, published statistics were studied and special records were collected directly from fishermen. The latter consisted of information transcribed from business records of pound-net operators, lent for the purpose, and since 1928, of information recorded daily on forms provided by the bureau. These records have proved of great value, and the cooperation of the 26 operators who kept these records is gratefully acknowledged.

Study of the causes of the changes in abundance occurring during the course of the investigation was continued during 1930. For this purpose, biological observations were made during part or all of the 1930 fishing season at each of the following field bases: Woods Hole, Mass.; Newport, R. I.; Montauk and Fire Island, N. Y.; Belford, Long Branch, Deal, Seaside Park, Beach Haven, and Wildwood, N. J.; and Hampton and Cape Charles, Va. In the course of these observations more than 100,000 fish were measured and 11,000 scale samples from squeteague were collected.

Chief progress has been made in analysis of the data relating to squeteague and scup. Studies of the scales and length frequencies of the former have provided a technique for age analysis of the commercial catch. These studies have further demonstrated distinct differences in rate of growth in several localities, the rate increasing from Chesapeake Bay northward. A remarkable feature of these

observations of age composition of the catch is the virtually complete absence of yearling squeteague in all three seasons, although fish a year younger and a year older are present. Not only are yearlings absent from the commercial catch, but they also are absent from the catches made by experimental trawls, seines, and hand lines in the bays where juveniles in their first summer are readily taken.

Study of published and specially collected statistics of yield indicate that fluctuations in central and southern New Jersey have been moderate and that squeteague are little, if any, less abundant than during the early years of the fishery. In New York and northern New Jersey, however, remarkable fluctuations, similar to those recorded from southern New England, were noted. In these localities, a spectacular increase in yield occurred in 1902. The increase persisted through 1908, but since that year the catch has fluctuated moderately about a level even lower than that which obtained before the increase.

It was expected that discovery of the causes of the minor fluctuation in recent years would cast light on the probable causes of larger changes in the past. This expectation has not been realized, for it appears that fluctuations during the course of the investigations are due largely to marked variation in the numbers of 2-year-old squeteague entering the fishery for the first time. Thus the general increase in yield of squeteague in New York in 1929 over that of 1928 was due almost entirely to the appearance of large numbers of squeteague of the 1927 year class. This year class continued to dominate the catch in 1930.

Seasonal distribution of the large catches between 1902 and 1908 was so markedly different from that of recent years as to suggest that quite different causes were concerned. Virtually all of the 2-year-old fish have appeared in the spring during the three years of scientific observation, while the few large fish taken have appeared during the summer and autumn. During the period of very large catches, the bulk of the catch was taken in the summer and autumn, the spring catches being actually less than those of recent years. This suggests that the large catches between 1902 and 1908 consisted of large fish and that their appearance was not heralded by unusually large catches of 2-year-old squeteague a few years prior to the period of abundance. This suggestion is confirmed by the testimony of living witnesses.

These facts suggest the hypothesis that migration, either from other coastal waters, or from an offshore reserve, is an important cause of such remarkable increases in abundance as those which occurred in New York and southern New England 30 years ago. Otherwise, it is scarcely credible that such extraordinary numbers of large fish, described as averaging from 3 to 5 pounds in weight, could have appeared without giving notice of their existence by marked increases in spring catches during the years immediately preceding their appearance as large summer fish.

The principal objective of further investigation will be the testing of the two hypotheses offered in explanation of these peculiarities of behavior on the part of the squeteague. These hypotheses are: (1) Stocks of squeteague north of Delaware represent one or more self-perpetuating units of population, in which successful local repro-

duction accounts for the annual increment to the stock; (2) local reproduction accounts for little or none of the increment to the stock of squeteague north of Delaware, the whole stock being maintained by migration of fish 2 years or more of age from southern waters.

The first of these hypotheses is supported by the fact that squeteague are known to spawn in Delaware Bay, and by the fact that juveniles occur in Delaware Bay, Sandy Hook Bay, Great South Bay, Fort Pond Bay, Narragansett Bay, and in the Wareham River at the head of Buzzards Bay. Moreover, the existence of local races is indicated by differences in rate of growth in several localities. If this hypothesis be correct, the absence of fish in their second summer must be explained. It is possible that they remain concealed locally or that they spend this period in southern waters or offshore.

Absence of fish in their second summer is consistent with the second hypothesis, for fish of this age are abundant in southern waters. In order to account for the differences in rate of growth of northern and southern fish, it is necessary to assume that migration is a selective process. This hypothesis is also in agreement with the facts disclosed by an investigation of spawning and nursery grounds in Delaware Bay. Results of this investigation may be summarized as follows:[2]

A very intensive spawning of squeteague occurs in May and early June off the west shore of Cape May, from about 1 mile to 3 or 4 miles north of Cape May Point, mainly along the 3–4 fathom contour. Single 20-minute meter-net hauls have yielded more than half a million squeteague eggs in this locality during the height of the spawning. Squeteague taken here by gill nets during this period were spawning freely. Although squeteague eggs were taken elsewhere in the bay, the quantities were small.

Intensive observations, however, failed to produce any evidence that these eggs hatched or that larvæ from them survived. Meter-net collections were taken at all depths from the surface to the bottom and as far away in all directions from the spawning area as the cruising range of the boat permitted. Only negligible numbers of larvæ, usually one or two specimens, were taken in the same nets which collected half a million eggs.

Later in the summer, in both years, young squeteague appeared in the bay and remained fairly abundant during the summer. The sizes of these juveniles were such that they can not be attributed to the spawning described above. They did not consist of a compact size group as would have been the case had they resulted from the brief and localized spawning described above, and other facts indicate that very small juveniles continued to be added to the stock in the bay long after cessation of intensive spawning there. As the majority of the young fish taken in the fall were much smaller than normal, there are grounds for believing that many of them may fail to survive.

These conditions contrast with those observed by John C. Pearson, who conducted a similar survey in Chesapeake Bay during 1929 and

[2] Summarized from a report by Prof. A. E. Parr, curator of the Bingham Oceanographic Foundation of Yale University, who has been in charge of the Delaware Bay survey.

1930. In that locality larvæ as well as eggs were found in both years, and length measurements indicated that juveniles grew regularly and attained, by the end of the season, a length commensurate with that of yearlings appearing in commercial catches in the spring.

Two years' observations in but one of the several northern localities frequented by juveniles are insufficient to prove that reproduction is always a failure, either in Delaware Bay or elsewhere. They do, however, indicate the need for continuation of observations in Delaware Bay and their extensions to other localities.

The most direct method of testing these hypotheses is a study of migrations and of the survival of marked juveniles. Unfortunately, squeteague are difficult to mark. Two field experiments in the tagging of this fish have failed to produce satisfactory returns. Although all external tags have so far failed in both laboratory and field experiments, the Woods Hole experiments have demonstrated that young squeteague will carry small strips of celluloid in the body cavity without injury. This mark is inconspicuous and will not be observed until the fish are cleaned. On the other hand, it may be applied to very small fish and probably will be retained indefinitely by the majority marked.

W. C. Neville has analyzed scup data collected in the course of the investigation, and he finds that this species has been subject to considerable fluctuation in yield during the past 40 years. The yield in New Jersey in 1926 was, save for 1908, the lowest of any year in which statistical canvasses were carried out. A remarkable recovery occurred in 1929; the pound-net catch arose to the highest total ever recorded and continued to be high in 1930. This phenomenon is seen to be the result of a high survival from the spawning of 1927. Scup of this year class appeared in large numbers in northern New Jersey in 1928; but as they were too small to be marketable, they had no effect on the reported yield. In 1929 and 1930 they were salable, and consequently the catch increased greatly. It is notable that the 1927 brood spawned in a year when the reserve of spawning adults was at a very low ebb, indicating that success of reproduction is independent of the spawning reserve within wide limits.

The yield of butterfish, although subject to considerable fluctuation, has been satisfactory in recent years. Age determination has proven difficult, as the scales are illegible and length frequencies difficult to interpret. The studies of H. M. Bearse, who has analyzed length-frequency data, indicate that dominance of the fishery by occasional large broods is largely responsible for the fluctuations which occur.

Spot, or Lafayette, is not ordinarily of much importance in New York and New Jersey. In 1926, however, the yield in New Jersey reached 1,217,000 pounds, and in New York 436,000 pounds. The observation of C. M. Breder, jr., of the New York Aquarium, to the effect that young spot, too small to market, were unusually abundant in New York Harbor in 1925 supports the view that the large yield in 1926 was due to an unusually large brood and that the spot may be added to the long list of species known to be subject to natural fluctuations caused by variation from year to year in success of reproduction.

CHESAPEAKE BAY INVESTIGATIONS

During the past year John C. Pearson has conducted for the bureau several investigations in the Chesapeake Bay region. A study of the seasonal distribution of pelagic marine fish eggs and young fishes at the mouth of the bay was begun in 1929 and continued throughout 1930, when field work was completed. The results of this study showed the annual occurrence of at least 40 species of pelagic young marine fish and also located the spawning grounds of the squeteague or gray sea trout. A report of this investigation is in course of preparation.

A recent important development is the winter trawl fishery off the Virginia and North Carolina coasts. This fishery has now grown to considerable proportions and is conducted from November to early spring by local and northern fishermen. An observer has been stationed at the leading Chesapeake trawling port to obtain records of the composition of the catch, the locations of the fishing grounds, and other data, and a report will be issued after the first season's observations.

Certain angles of one of the country's leading recreations were described by Mr. Pearson during the past year when a survey of sport fishing possibilities in Chesapeake Bay was completed. A concise description of angling, the localities and facilities for sport fishing, and the leading food and game fishes of the region has furnished material for a paper entitled " Sport fishing in Chesapeake Bay."

INDEPENDENT ACTIVITIES AT THE FISHERIES BIOLOGICAL LABORATORY, WOODS HOLE, MASS.

The Woods Hole laboratory under the direction of O. E. Sette has continued to afford facilities for the experimental phases of research on commercial fisheries problems. These facilities have been of particular value in the rearing of juvenile squeteague, scup, and sea bass in aquaria under known temperature and food consumption. These observations have verified the conclusions as to the growth rate of wild stock, have indicated the probable temperature of their winter habitat, and have paved the way for further experiments on effects of environment.

Of equal importance have been the observations on fish marked with various styles of tags. The marking of fish to determine their migrations, the intensity of fishing, etc., is one of the most important phases of fisheries research. Its greater use has been prevented through lack of suitably designed tags. Through the laboratory experiments, causes of failure have been observed and corrected. A type of tag suitable for flounders, scup, and sea bass has been developed; and experiments continue on cod, haddock, and squeteague. This tag consists of an improvement of the Scottish plaice label, used so successfully in European waters. The improvements consist of substitution of pure nickel for silver wire, the addition of printed return instructions and of reduction in thickness and diameter of the disks. The value of these improvements is well established by laboratory experiments.

During the summer months the bureau's activities in plankton studies, observations of spawning of fishes, larval development and growth of juvenile fishes in the vicinity of Woods Hole were centered at the laboratory. This work is seriously handicapped through lack of a boat capable of operating an otter trawl of sufficient size to catch fishes for experimental work. Provision of new floating equipment at the laboratory is a matter of utmost urgency if research work is to continue.

In accordance with the bureau's long-established policy of encouraging independent research in marine biology and related subjects, the facilities of the laboratories at Woods Hole, Mass., were made available to a number of investigators from various educational institutions. Personnel so accommodated at Woods Hole included: Dr. Robert Payne Bigelow, Massachusetts Institute of Technology, stomatopoda of the *Albatros* eastern Pacific expedition; Leon C. Chesley, Duke University, enzymes of fishes; Dr. N. A. Cobb, Department of Agriculture, nematodes; Paul S. Conger, U. S. National Museum, diatom investigations; William L. Doyle, Johns Hopkins University, pituitary of *Mustelis canis* and *Lophius piscatorius*; Kendal W. Foster, Harvard University, the blue phase in coloration of Fundulus; Dr. I. E. Gray, Duke University, respiration of fishes; Dr. F. G. Hall, Duke University, respiration studies on marine fishes; Dr. John C. Hemmeter, Johns Hopkins University, Langerhans organ of Lophius; Dr. Edwin Linton, University of Pennsylvania, trematodes of fishes; Raymond W. Root, Duke University, respiratory function of the blood of marine fishes; Wellford Taylor, Princeton University, Crepidula eggs and pituitary of rats and cats; Gerald Thorne, Department of Agriculture, nematodes; Sam R. Tipton, Duke University, respiration of fishes; Leonard G. Worley, Harvard University, cilia of marine and fresh-water animals.

SOUTH ATLANTIC AND GULF FISHERY INVESTIGATIONS

SHORE FISHES OF NORTH CAROLINA

The investigation relative to the development of fish eggs and young fish undertaken several years ago was continued throughout the year by Dr. Samuel F. Hildebrand, assisted by Louella E. Cable. A special effort was made to secure missing larval stages of several species and to collect sufficient samples for determining the rate of growth of several commercial species by making large series of length measurements at frequent intervals. Pronounced progress was made in both lines of endeavor.

The study of the large collection of young fish that has been accumulated from collections made locally and secured from elsewhere was pursued energetically. A report on the subject was completed during the year. Preparation of drawings and descriptions on the development of other species was continued and fairly complete data for several forms, not included in the recently published paper, are at hand.

Miss Cable has undertaken, also, a critical study of the life history of the pigfish (*Orthopristis chrysopterus*). For the determination of the growth, age, and span of life she is making use of otoliths and scale characters in addition to length measurements.

TERRAPIN CULTURE

Experiments in diamond-back terrapin culture, carried on at the biological station at Beaufort, N. C., under the direction of Dr. Samuel F. Hildebrand, progressed very satisfactorily.

Egg production from the entire brood stock was high and a fair rate of fertility prevailed. The hatch for the season of 1930 consisted of 7,054 young. The entire hatch of the season was placed in the brooder house and a large series of experiments pertaining to feeding and other treatment is being conducted.

Experiments with the 1929 brood again showed that salt water is a better medium for the young in the brooder house than fresh water, for the death rate was considerably lower and the growth rate slightly higher among the animals kept in salt water than those in fresh water, although the last-mentioned difference may have been due to the greater loss in fresh water among the smaller and weaker animals. Among the various foods and combinations of foods used, a mixture of fresh fish and oysters gave the best results when rate of survival and growth are both taken into consideration. Liver, beef, and vegetables did not give satisfactory results.

No epidemics occurred among the young animals, although "sores," a disease of unknown origin and for which no cure has been found, again were present. Among 7,782 young of the 1929 brood placed in the brooder house, 3.4 per cent died of this cause. "Soft-shell," a condition correlated with a failure to feed and resulting in a generally emaciated condition, caused 10.7 per cent of deaths, and all other causes resulted in 3.6 per cent of deaths. The total number of deaths, prior to liberation of the brood of 1929, or during about the first 8 or 9 months of life, therefore, was 17.9 per cent, which is regarded as a rather low death rate.

The surviving animals, exclusive of 200, which were retained for further experimentation, were turned over to the North Carolina Department of Conservation and Development for liberation in suitable areas. The animals had attained a length on the median line of the plastron of about 1⅓ inches (32.4 millimeters) which represents a growth of slightly more than ¼ inch (5.4 millimeters) since hatching. Many of the animals, however, were 1½ inches and over in length, the average being reduced by numerous "runts" which always have been present during the course of this work. The average rate of growth shown is not the best obtainable with our present state of knowledge, because certain foods used, although showing unsatisfactory results, were continued throughout the season in order to emphasize the results.

Practical results from the liberation of young terrapins are becoming more and more evident in the commercial catches from the frequent occurrence of terrapins which bear the marks made at the laboratory on a marginal plate upon liberation.

BAY SCALLOP

At Beaufort, N. C., Dr. J. S. Gutsell has been conducting investigations as to the commercially important bay scallop, which nationally is about equal to the soft clam in commercial value. The facts learned offer a basis for wise conservation or for active development through scallop culture.

Two reports based on these investigations have been prepared. One appeared in 1928, and the other, The Natural History of the Bay Scallop, went to press in 1930.

POLLUTION OF STREAMS IN WESTERN NORTH CAROLINA

At the request of the Department of Conservation and Development of North Carolina, Dr. J. S. Gutsell in 1930 undertook an investigation of the effect of wastes from factories at Sylva, N. C., upon the fish of the Tuckaseegee River. The factories located at Sylva consist of a tannery; a plant for the manufacture of commercial tannery extract; and a plant for the manufacture, by means of the semichemical pulping process, of paper board. The wastes are discharged into Scotts Creek about 2 miles from its entrance into the Tuckaseegee River. Most of the complaint for destroying bass fishing is against the paper-board waste which blackens the river to its mouth some 35 miles below.

Experiments were made with fish in various dilutions of the wastes from the different plants. Fish were also placed in wire cages in Scotts Creek and the Tuckaseegee River above pollution and for as much as 19 miles below, and a study of the fish and bottom fauna above and below the point of entrance of pollution was made. The paper-board waste had no definite lethal effect in 10 per cent concentration upon the fish in diluted wastes. The discharge from the extract plant ordinarily was almost without effect even in high concentration and with its small volume is not an important factor. The tannery waste was lethal to trout down to 5 per cent concentration. However, this is a much higher concentration than occurred in the Tuckaseegee River at its lowest stage during August or September, 1930. Cage experiments revealed no definite lethal action of the pollution of the Tuckaseegee River on trout or bass. In general, fish were found as abundant in the polluted section as above it, although suckers and darters were scarce in the river from Scotts Creek 20 miles downstream or as far as the river was examined for fish.

Aside from appearances the greatest discovered effect of the pollution was on the bottom fauna. In particular stone flies and May flies were scarce in the polluted section. The effect on the bottom fauna is attributable to the deposition of organic matter from the paper-board waste.

There are complaints that harmful substances occasionally are discharged by the plants at Sylva in much greater amounts than ordinarily and that many fish are killed thereby. Although this was not disproved, no direct evidence of it was found and no definite report obtained of such an occurrence in recent years.

The investigation revealed no evidence that the wastes from any of the Sylva plants is directly injurious to fish in the Tuckaseegee River. Most fish, including bass, were found as numerous below the entrance of pollution as above it. The only locally esteemed fish which must be excepted is the red horse sucker. However, the deposition of the organic matter from the paper-board waste adversely affects the bottom fauna and so stands in the way of full possible improvement, as from stocking. This same waste, by its discoloration of the water, makes angling unattractive and discourages stock-

ing. There is also the possibility that this discoloration prevents the upward migration of bass from the Little Tennessee River, into which the Tuckaseegee River discharges, and so is responsible for the reported loss, coincident with the discoloration of the stream, of the bass fishing from above Bryson to the mouth of the Tuckaseegee River.

At Old Fort, N. C., on the Catawba River, in close association are a tannery and a plant for the manufacture of tannery extract. Doctor Gutsell made a brief investigation of the effects of pollution from this source.

The Catawba River proved to be so polluted for over 2 miles that heavy sludge deposits occurred in the stream and along the margins. The bottom fauna was remarkably altered. For about a mile below the combined outfall no fish were found and at about 2 miles the stream was poor in species and individual fish. At about 4 miles conditions had much improved. The bottom fauna was more nearly normal and fish life more abundant and varied. At a point about 8 miles below the factory outfall the bottom fauna proved to be much like that above the point of pollution, indicating that recovery, at least in rapid portions of the stream, was substantially complete.

Reports on the Tuckaseegee River and the Catawba River investigations were submitted early in December to the North Carolina Department of Conservation and Development.

During the investigation of stream pollution a considerable collection of fishes was made and turned over to Dr. Samuel F. Hildebrand for identification. Quite a number of forms proved very puzzling and the study of the collections showed clearly that the fishes from the western part of North Carolina are still quite imperfectly known and inadequately described.

SHRIMP

The shrimp fishery which is prosecuted on a commercial scale from Beaufort, N. C., to Corpus Christi, Tex., produced 113,000,000 pounds of fishery products in 1929 and ranks fifth in value and sixth in volume among all the fisheries of the country. This yield is two and one-half times the quantity produced in 1918, and this rapidity of expansion has caused great anxiety for the future of the industry. Lacking adequate funds and personnel, the bureau formerly was unable to satisfy the many requests for information or advice on questions of regulation of the fishery. Although of commercial importance for half a century, no adequate study of the shrimp had ever been made. The passage of the 5-year program bill, however, made it possible for the bureau to accede to these requests for an investigation, and plans were laid early in the fiscal year 1931 to start an adequate program of study which would require several years for its completion, and to attack all phases of the shrimp problem at a number of points representing the entire range of the fishery.

Dr. Frank W. Weymouth, professor of physiology at Stanford University, who has wide experience in fishery research, was selected to supervise this investigation, and, although he will not begin active duty until early in 1931, a staff of assistants was organized to begin

preliminary observations. Dr. James S. Gutsell started studies on the development and early life history of the shrimp at Beaufort, N. C., and W. W. Anderson was stationed at Brunswick, Ga., to observe the fishery.

An important feature of the present plans is extensive State cooperation. The States to whom these resources belong, even though they may have no research division, often have valuable local facilities which, coordinated and supplemented by bureau aid, can obtain valuable results. A cordial spirit of cooperation has been shown

FIGURE 3.—Experimental fishing for shrimp in Georgia. A sample of the shrimp catch is measured for records of growth and fishes taken are sorted according to species and recorded

by the majority of the States; active participation in the program has been undertaken by Georgia and Louisiana, and negotiations looking toward a similar action are under way in Texas.

Last September Commissioner Peter S. Twitty, of Georgia, took the initiative in a biological investigation of Georgia's fisheries by hiring an investigator and two boatmen. Since that time they have been operating an experimental shrimp trawling vessel furnished by the bureau along the entire coast of Georgia and the northern coast of Florida, and valuable data on the effect of shrimp fishing upon other economic species have been accumulated. A survey is being made of the shrimp fishery and detailed studies are being conducted on

the growth, migrations, and habits of the shrimp, as well as the degree of injury to food and game fishes resulting from the destruction of immature fish by the shrimp trawlers in sounds and rivers.

In Louisiana a carefully drafted statute approved July 11, 1930, required the commissioner of conservation to create a bureau of statistical and biological research and appropriated the sum of $50,000 to finance the compilation and study of scientific data concerning the State's natural resources. Commissioner Robert S. Maestri has given effect to this statute by setting aside a budget sufficient for an immediate investigation of the shrimp, and plans are being completed for a joint investigation with the U. S. Bureau of Fisheries.

ACTIVITIES OF THE FISHERIES BIOLOGICAL LABORATORY, BEAUFORT, N. C.

The work of the Beaufort (N. C.) biological station is mentioned in the sections of this report dealing with the investigations by the bureau's staff of shore fishes, diamond-back terrapin culture, shellfish investigations, and stream-pollution studies. The facilities of the station were made available to several independent investigators. Prof. H. V. Wilson, of the University of North Carolina, engaged in the study of the embryology of sponges. Mrs. Henry R. Fuller, graduate student of the University of North Carolina, studied the embryology and local distribution of certain annelids and sea urchins. Miss Ezda Deviney, of the Florida State College for Women, experimented with the regeneration of several species of ascidians from cuttings of the adult animals. Dr. Hoyt S. Hopkins, of the New York University, continued his studies of previous years concerning the rate of growth of the hard clam (*Venus mercenaria*) and also the respiration of this mollusk and other bivalves of the vicinity. Dr. W. C. George, of the University of North Carolina, continued his observations of previous summers on ascidian blood and prepared a manuscript on this investigation. Prof. C. M. Child, of the University of Chicago, performed some experiments during the winter months on the physiological polarity and on the scale of organization on Tubularia and some other hydroids, and in sponges after the dissociation of cells. Dr. L. G. Barth, National Research Fellow, also working during the winter months, measured the electrical potential differences of reconstituting pieces of the hydroid, Tubularia. Prof. Z. P. Metcalf, of North Carolina State College of Agriculture and Engineering, made some observations on the ecological relationship of the animals inhabiting the sand dunes and flats of Bogue and Shackleford banks. Dr. Bert Cunningham, of Duke University, studied the relationship of temperature to the rate of growth of diamond-back terrapin embryos, and he also secured some eggs with embryos for future study.

The facilities of the station were also utilized by investigators of the U. S. Chemical Warfare Service and of the U. S. Coast Guard for testing samples of wood treated against marine borers.

ICHTHYOLOGICAL STUDIES

Over a period of a couple of years Dr. Anatasio Alfaro of the National Museum of Costa Rica submitted small collections of fishes from that country for identification. The determinations were made

by Doctor Hildebrand, and the collections contained a few species which were new to the fauna of Costa Rica. In other instances the range of distribution was extended within that country, and, furthermore, the study revealed some noteworthy facts which were published in Copeia in 1930.

The systematic study of the Texas fishes mentioned in previous reports has been expanded by Isaac Ginsburg to include the entire Gulf coast of the United States. This fish fauna forms a complex whole in which it is first of all necessary to clearly distinguish between the species in order to understand their complex interrelationship and the mutual influence which one species exerts on another.

With this object in view Mr. Ginsburg spent part of the summer season on the Gulf coast collecting and making observations on the coasts of Louisiana, Alabama, and Florida. Most of the work was done at Grand Isle, La., where quarters and cooperation were offered by the Louisiana State University. A good series of the various species obtainable at that time of the year was preserved for study. A study of this material has shown that important corrections will have to be made in our present-day ideas regarding the status of quite a number of the species and their relation to fishes of adjacent regions. It is intended to publish a series of shorter papers clearing up such moot points while the general project is in progress. A paper on a common species of goby based on these studies has already been prepared and submitted, and other papers of a similar nature are in preparation.

GREAT LAKES FISHERY INVESTIGATIONS

In 1930 the Great Lakes investigations under the direction of Dr. John Van Oosten were conducted on Lake Erie, Green Bay, Lake Michigan, Saginaw Bay in Lake Huron, and on Lake Champlain. The investigations conducted on Lakes Michigan and Champlain were new enterprises started in 1930, while those on Lake Erie and on Saginaw Bay were continuations from previous years.

LAKE CHAMPLAIN

The Lake Champlain investigation was a joint undertaking with the Dominion Government of Canada and was conducted under the auspices of an International Fact-finding Commission composed of James A. Rodd, representing Canada, and Dr. John Van Oosten, representing the United States. Six investigators took part in the field work which covered a period of about four months. The chief objective of this investigation was the accumulation of scientific data pertinent to the question of determining the effect of commercial seining by Canadian residents in Missisquoi Bay on the abundance of the pike perch in the United States waters of Lake Champlain. This question involved a study of the chief features of the biology of the yellow pike perch, yellow perch, smelt, and suckers. In addition to determinations of abundance, length, weight, sex, and maturity, large numbers of stomachs were collected and more than 8,000 yellow pike perch were tagged to determine the extent of its migration in Lake Champlain.

LAKE MICHIGAN AND GREEN BAY

The Lake Michigan and Green Bay investigations were also cooperative undertakings, the work being liberally supported financially by the Conservation Departments of Michigan and Wisconsin and by a group of four fish net and twine companies located in the Great Lakes area. The twine companies donated some 90,000 feet of experimental gill netting valued at about $3,200. The Lake Michigan program was designed primarily to determine whether it is possible to fish gill nets for chubs, species closely allied with the whitefish, without destroying large numbers of small, immature lake trout as actually occurs at the present time. This problem in its broader aspects is a complicated one and involves not only a study of the selectivity of gill nets of various-sized meshes on lake trout

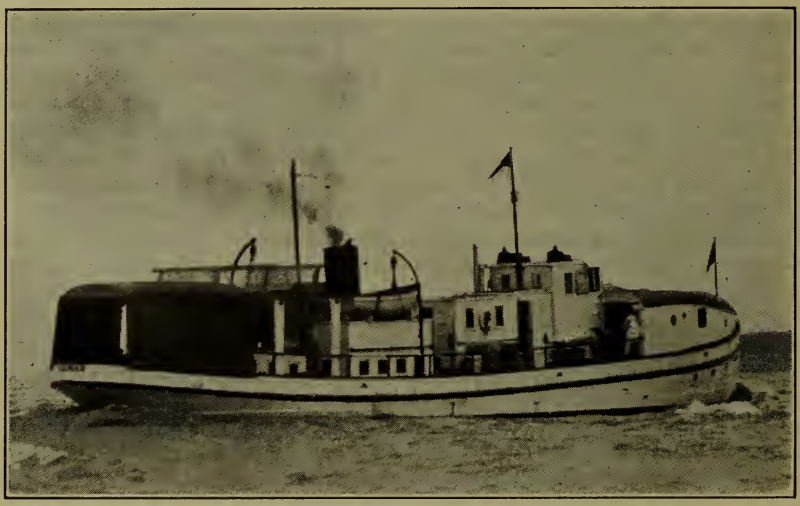

FIGURE 4.—The U. S. F. S. *Fulmar* equipped for experimental gill-net fishing in Lake Michigan. A unique feature of this equipment is the drying reels for nets. They permit the vessel to fish from a different part each day without returning to dry nets

and chubs at various seasons and in various areas, but also a consideration of the following questions: Effect of various methods of stringing chub nets on the catch of lake trout, distribution and migration of chubs and lake trout at various seasons and in various areas of the lake and the factors involved therein (currents, depths, temperature, bottom, plankton, food, etc.), races or species of lake trout, the effect of bait nets on the food supply of lake trout and on the abundance of chubs, the destructiveness to immature lake trout and whitefish of hooks, large-meshed gill nets, pound nets, and deep trap nets. In addition, as many data as possible were collected on the natural history and life history of the various species of coregonoids and lake trout.

The bureau's vessel, *Fulmar*, a boat 102 feet long, has been fully equipped for experimental fishing and has been manned by experienced commercial fishermen, in addition to the scientific personnel. The Lake Michigan investigations were begun June 17 and discon-

tinued November 19, 1930. The program was interrupted from August 22 to September 20 due to the installation of a new main engine, and the cleaning and repairing of the boat.

Before resuming operations on Lake Michigan, a short survey was made of the herring fisheries in Green Bay at the special request of the Conservation Commission of the State of Wisconsin. This work, carried on from September 20 to October 4, was designed to determine by experimental fishing whether a shifting of the line of demarcation between bay fishing and lake fishing in Wisconsin waters would be detrimental to lake trout and chubs. This line, as defined by law, now extends from the mouth of the Menominee River in Marinette County to Limekiln Bluff in Door County, a point slightly westward of Little Sturgeon Bay. The waters northeast of this line are defined as belonging to Lake Michigan and fishing therein is governed by the Lake Michigan regulations which prescribe among other things a 2⅝-inch mesh gill net for chubs and herring in contrast to the 2⅜-inch mesh gill nets permitted in the waters southwest of the line, defined by law as Green Bay.

LAKE ERIE

One investigator was assigned to the fishery work on Lake Erie conducted during the period April 24 to December 4. In addition to the collection of samples of the commercial catch, a careful study was made of the fishing characteristics of a newly designed trap net evolved from our previous experimental work. The field data indicate that by the adoption of this net for commercial fishing in Lake Erie significant millions of immature fish will be saved in the lake each year, a large amount of labor will be eliminated in the sorting of fish by the fishermen, and thousands of dollars will be saved the industry by the reduction of the wear and tear on nets during sorting.

Field operations on the limnology of western Lake Erie, carried on by Dr. Stillman Wright in cooperation with the Ohio Division of Conservation, have been completed. Observations were made during the period April to October. The combined staff of six investigators made an intensive study of the chemistry, plankton, and bottom organisms near the mouths of important rivers in an attempt to determine accurately the limits of polluted areas. Reports by the various investigators are now being prepared. When completed, they will be incorporated into a single report covering five years of study.

LAKE HURON

Field work on the experimental fishing of pound nets in Saginaw Bay was completed during the summer of 1930. This work described in previous reports covered a period of two years and was carried on jointly with the Conservation Department of the State of Michigan.

WISCONSIN INLAND LAKES INVESTIGATIONS

The investigations of the inland lakes of northern Wisconsin which the bureau conducted in cooperation with the Wisconsin geological and natural history survey in 1927 and 1928 were resumed

in the summer of 1930. Dr. Ralph Hile of the Bureau of Fisheries and Edward Schneberger of the University of Wisconsin made collections of fish scales for age studies during the months of July and August and most of September, obtaining data from a total of 4,921 fish.

The collections of three summers have made available for growth study, material from approximately 12,000 fish. The forms most numerous are the perch, cisco, rock bass, bluegill, and sucker. There are also included 1,175 game fish—muskellunge, pickerel, pike perch, and black bass. A large part of the game fish have been furnished by sport fishermen who are supplied with packages of scale envelopes, along with directions for taking the desired data.

The study of the growth of the perch and the game fish is being made by Mr. Schneberger, while Doctor Hile is investigating the rock bass, bluegill, and cisco. In the past, collections have been made from a considerable number of lakes, but it is planned, in the future, to concentrate efforts on a few selected typical lakes, so that attention may be given to growth problems of a more special nature.

LIMNOLOGICAL STUDIES

Investigations were continued on the lakes of northeastern Wisconsin during the summer of 1930 by the Wisconsin geological and natural history survey. The Trout Lake laboratory of the survey was opened on June 20 and work was continued until September 15. These studies are entirely supervised and largely financed by the survey, but in recognition of the bureau's modest cooperation the following report has been submitted by Prof. Chancey Juday, and because of its intimate relation to other undertakings by the bureau is published here.

The field party consisted of E. A. Birge, C. Juday, Edward Schneberger, Hugo C. Baum, J. P. E. Morrison, Ruby Bere, J. B. Goldsmith, C. A. Herrick, biologists, and Frederick J. Stare and Theodore Setterquist, chemists. Dr. Ralph Hile of the U. S. Bureau of Fisheries also was at the laboratory in cooperative work on the fish problem. During the month of August, W. L. Hafner of Armour Institute, Chicago, was employed in connection with hydrographic surveys of a number of lakes.

The field studies included such items as hydrographic survey of 20 lakes, the temperature, transparency, color, the conductivity of the water and the rate at which the sun's energy is absorbed by the water in different types of lakes. The chemical determinations consisted of hydrogen-ion concentration, free and fixed carbon dioxide, dissolved oxygen, oxygen consumed, and calcium. The biological phases of the work consisted of quantitative studies of the net and centrifuge plankton, a further study of the aquatic Mollusca of the district, the leech fauna of a number of lakes, the collecting of fish for growth studies, and a study of the external parasites of the fish.

In the hydrographic work, 20 lakes were surveyed and sounded. The area and volume of 19 of these lakes have been determined so far. The contours of Trout Lake are very complicated and the measurements and computations on it have not been completed. The area of the other lakes ranges from 1.2 to 230 hectares and the volume from 66,780 to 23,302,000 cubic meters. The determination of the volumes of these lakes makes it possible to ascertain approximately how much organic matter and dissolved salts are contained in the entire body of water.

The work was extended to 50 new lakes in the district during the summer; this makes a total of 529 lakes that have been visited in the six summers (1925–1930) that the investigation has been in progress. This completes the general survey of the more important lakes of this region, and it is now the

plan to take up more intensive work on a few lakes which represent the various types that have been found in the district.

In 1930 as in 1929 a large amount of work was done with the pyrlimnometer on the relation between solar radiation and the lakes. A new line of study was entered upon, namely the composition of the energy spectrum as determined by the use of light filters. It was found that in this way accurate and detailed knowledge can be secured of the distribution of the radiation at different depths in lakes, to the several regions of the spectrum. Since at depths of 1 meter, and over, practically only visible radiation remains, this study is concerned with the quantitative distribution of light in the lakes. It is possible to ascertain not only the quantity of light present at any depth within the competence of the instrument, but also the percentage of the quantity that is present, as, say a yellow light, or from the region of the spectrum between 5000–6000 Å. It is expected that this study will serve as a basis for the investigation in lakes of the relations between light and the growth of algæ—the fundamental food supply of lakes.

Work was continued on the studies of 1929 relating to the transmission of total radiation also as well as that of the several colors. The season was very favorable for these studies. Fifty-one lakes were visited, many of them several times, and 74 series of observations were made which included more than 9,700 readings of the pyrlimnometer.

Determinations of hydrogen-ion concentration, carbon dioxide, dissolved oxygen, oxygen consumed, and calcium were made on 239 different lakes during the summer. The dry organic matter in the centrifuge plankton was determined on 252 samples and 139 samples of water were evaporated in order to obtain residues for further chemical analyses.

A wide variation in organic and mineral content was found in the various lakes; the dry residues ranged from a minimum of 13 to a maximum of 116 milligrams per liter of water. Likewise there was a wide range in the conductivity of the water, varying from 8.5 to 115 when expressed in terms of the reciprocal of the megohms resistance. The color of the water in these lakes varied from none to a maximum of 240 based on the U. S. G. S. standards of the platinum-cobalt scale. This wide variation in color causes a correspondingly wide variation in the rate of absorption of the sun's energy by the waters of the various lakes.

The hydrogen-ion concentration ranged from pH 4.8 to 8.6; the lowest values were found in the very soft water lakes and the highest ones in the lakes with considerable amounts of fixed carbon dioxide and with abundant growths of phytoplankton. The fixed carbon dioxide ranged from 0.7 to 31 milligrams per liter of water; the smallest amounts were noted in lakes that have neither an inlet nor an outlet.

The dissolved oxygen in the surface water varied from 5.8 to 10.6 milligrams per liter; the smaller quantities of oxygen were found in lakes that possessed boglike conditions while the larger amounts came from lakes supporting an abundant growth of phytoplankton.

The oxygen consumed, as determined by the permanganate method, ranged from about 1 milligram to 26 milligrams per liter of surface water. It was usually somewhat lower in the bottom than in the surface water of the deeper lakes. This determination gives a general idea of the amount of organic matter present in a readily oxidizable condition in the water. There is a certain degree of correlation between the quantity of oxygen consumed and the amount of vegetable coloring matter in the water.

The quantitative studies of the iron showed that only a small amount is present in the surface water. The quantities ranged from a trace to 0.26 milligram per liter of water in the various lakes. Larger amounts were found in the lower water of the deeper lakes in some cases, especially where the dissolved oxygen all disappeared from the lower stratum in summer.

The quantity of calcium in the surface water varied from a minimum of a little less than 0.2 milligram per liter to a maximum of 20 milligrams, a hundredfold difference. The lakes that have neither an inlet nor an outlet possess the smallest amounts. The quantity of calcium is approximately 50 per cent as much as that of the fixed carbon dioxide, more especially when the fixed carbon dioxide is 5 milligrams per liter or more.

Several thousand specimens of the aquatic Mollusca have been collected in this lake district during 1929 and 1930. A taxonomic report on the various species and their distribution in that region is almost completed. One of the

interesting facts brought to light in this phase of the work is that the small bivalves belonging to the genus Pisidium occur in considerable numbers in some of the very soft water lakes, where the water has a pH of 5.2 and only 0.15 milligram of calcium per liter.

Specimens of leeches were obtained from 38 lakes, but no thorough survey of the leech population was made on any of them. A total of 18 different species was represented in the various lakes.

In the study of the external parasites of the fish, 1,300 specimens belonging to 11 different species of fish were examined. Of this number only 28 specimens, or a little more than 2 per cent, harbored parasitic copepods. The largest number of these parasites found on a single fish was about 20 Ergasilus on a rock bass from Allequash Lake. Most of the other 27 parasitized specimens carried only a small number of the copepods, two or three up to a dozen. Only two forms of parasitic copepods were found on these fish and both of them represent new species. A report on them is now ready for publication. Leeches were found on only 10 of the 1,300 fish examined.

Over a thousand fish were examined for internal parasites; of this number 657 were yellow perch, 166 ciscoes, 170 rock bass, and a small number of specimens belonging to two or three other species. The different species of fish showed very marked differences in the percentage of infestation in the various lakes. In the ciscoes, for example, 66 per cent of the specimens from Muskellunge Lake were free of internal parasites while only 8 per cent of those from Silver Lake were not parasitized. Only 3 per cent of the yellow perch from Muskellunge Lake gave negative results, while almost 98 per cent of those from Weber Lake were negative. Specimens of rock bass from three lakes (Muskellunge, Nebish and Silver) were examined and all of them were parasitized. Also the smallmouth black bass were found to be heavily parasitized in Nebish and Silver Lakes. The parasites belonged to four different groups, namely, Myxosporidia, Trematoda, Cestoda, and Acanthocephala.

During the present academic year (1930–31) 5 research assistants are working on the material that was collected during the summer of 1930 and in previous summers; 3 of these assistants are chemists and 2 are biologists. One of the chemists is making quantitative determinations of the organic carbon and organic nitrogen in the lake residues, another is making a similar study of silica and calcium, while the third is working on magnesium and hydrocarbons. One biologist is counting the organisms in the net and centrifuge plankton catches, and the other is studying the scales of the yellow perch in order to determine the rate of growth of this fish in different lakes.

At the present time (December, 1930) five different reports on various phases of the work are practically ready for publication; at least four of them will be published before the 1st of July, 1931.

PACIFIC COAST AND ALASKA FISHERY INVESTIGATIONS

On November 1, Dr. Willis H. Rich who, in conjunction with the late Dr. Charles H. Gilbert has planned and directed the scientific work of the Bureau of Fisheries in Alaska for the past several years, resigned from his position as director of Pacific Fishery Investigations to become a member of the faculty of Stanford University. The bureau hopes to continue to have the benefit of his experience and advice in the future. J. A. Craig is now acting director of the Pacific coast laboratory.

No new investigations have been initiated during 1930. All of the previously planned programs have been carried out, and satisfactory progress has been made. These investigations have as their objective the solution of biological problems related to the conservation of the fisheries of Alaska.

ALASKA SALMON

Tagging experiments.—The salmon-tagging experiments, which have been carried on in Alaska since 1922, were continued during the season of 1930. Approximately 3,500 tags were attached. About

2,000 of these were put on salmon taken from traps in the region of Cape Fox, Sitklan, and Kanaganut Islands, and the remainder on salmon taken from traps in Clarence Strait both north and south of the entrance of Kasaan Bay.

The experiments in the Cape Fox district were undertaken at the request of the Canadian fishery authorities and were designed to test the extent to which these traps caught salmon bound for streams in British Columbia. Those in the region of Kasaan Bay tested the extent to which the traps near the entrance to Kasaan caught fish bound for the spawning grounds contiguous to that bay.

Approximately 1,000 tags have been returned with data as to the time and place of recapture. These data are now being collated, but the study is still too incomplete for definite conclusions. A report covering the results will be presented in the near future. The work was carried out by Frank Hynes of the Alaska service under the general direction of Dr. W. H. Rich.

During the year a report by Seton H. Thompson, dealing with the tagging experiments of 1929 was published in the Bulletin of the bureau as Document No. 1084.

Statistics of the Alaska salmon fisheries.—The study of the statistics of the Alaska salmon fishery has been continued by Dr. W. H. Rich and E. M. Ball of the Alaska service. During the past year a second section was completed and is now in press. The first section published in 1929 dealt with the fisheries of Bristol Bay and the Alaska Pensinsula and the second section covers the territory from Chignik eastward to and including Resurrection Bay. Data are presented showing, as far as possible, the catches in each locality from the beginning of the industry up to 1927. It is not possible to draw any satisfactory general conclusions since each small geographical district represents a separate unit. It is of interest to note, however, that many of the smaller red-salmon streams show extreme depletion throughout the district considered and a more moderate degree of depletion is found in even the large red-salmon streams. With few exceptions there is no evidence from the data presented that serious depletion has affected any of the other species.

Karluk red-salmon investigations.—The study of the returns from known escapements of spawning salmon, which has been adequately described in previous reports, was continued during the year of 1930. Data were secured on the return of 7-year fish from the 1923 escapement, of 6-year fish from the 1924 escapement, of 5-year fish from the 1925 escapement, and of 4-year fish from the 1926 escapement. The data are now complete for the escapements of 1921, 1922, and 1923. The escapement of 1921 consisted of about 1,500,000 fish, and the returns were approximately 3 to 1. The escapement of 1922 totaled about 400,000 fish, and the return was approximately 5 to 1. The escapement of 1923 numbered 695,000 fish, and the return was approximately $2\frac{7}{10}$ to 1. Valuable as are the results so far at hand, many more data will be necessary before any definite conclusions can be drawn regarding the situation.

The marking experiments, started in 1926, were continued. Fifty-five thousand red-salmon fingerlings were marked as they were migrating to the sea. The commercial catch was sampled for the return of marked fish from the marking of 1927, 1928, and 1929,

but on account of the poor run and consequent very limited catch, the data secured were inadequate as a basis for definite conclusions.

Two trips were made to Karluk Lake. Limnological data were collected on each trip and observations were made as to conditions on the spawning grounds. This investigation has been carried on by Dr. Willis H. Rich, who was assisted by J. T. Barnaby.

Chignik red-salmon investigations.—An investigation of the red-salmon runs of Chignik River, Alaska, has been continued by Harlan B. Holmes, associate aquatic biologist, assisted by Sidney B. Hayes and Hugh R. Israel, temporary assistants. Unusual irregularities in the growth and migrations of the fish are making it necessary to devote considerable attention to preliminary problems before attacking the basic problem of determining how many fish must be permitted to pass up the river to spawn in order to produce the greatest surplus to be taken by the commercial fishery. These preliminary problems were discussed in the report for 1929. Investigation of them was started in 1928 by a study of the seaward migration of fingerlings. In 1929 the work was extended to include studies of the life of the young fish in fresh water and methods of sampling the run of mature fish. The run of mature fish in 1929 was unfavorable for the study of sampling because the age composition of the run was unusually constant. Plans were made to repeat extensive sampling in 1930, but again conditions were unfavorable; this time as a result of a small run that made it necessary to prohibit commercial fishing for the greater part of the season.

The study of the young fish in fresh water was continued in 1930, particular attention being given to the fish in Chignik Lake, the lower of the two lakes, and to the seaward migrants. The complex situation observed in 1929 was found to prevail again in 1930. Fish ranging from fry that had recently emerged from the gravel of the spawning beds to fingerlings 10 centimeters in length were found throughout the season. Between these limits of size they were distributed in an array that practically defies age analysis by means of length frequencies. It is hoped, however, that further analysis of the data accompanied by a study of the scales of the fish will make it possible to determine the age of the fish with reasonable certainty.

The seaward migration of fingerlings, as in previous years, was found to extend throughout the summer. Fifty thousand of the migrants were marked by the removal of two of their fins. The recovery of some of these marked fingerlings several weeks after they had been marked confirmed other evidences of a leisurely migration, a condition quite different from that at Karluk for example, where several million fingerlings pass down the river and disappear in a period of a few weeks. The fingerlings were traced even into the ocean where they were found in all the neighboring bays for the greater part of the summer.

Pink-salmon investigation.—This investigation is concerned with the application of the " parent stream " theory to the life history of the pink salmon and with the survey of the streams in which they spawn. The latter is being made for the purpose of ascertaining some of the biological factors underlying the fluctuations in their abundance. Dr. F. A. Davidson has had charge of these investigations.

In February of 1930, 36,000 pink-salmon fry were marked at the Duckabush hatchery on Hoods Canal, Washington. The marking was accomplished by means of clipping their dorsal and adipose fins. This is the first time that the marking of pink-salmon fry has been accomplished. The runs in Duckabush River and neighboring streams of Hoods Canal will be carefully examined in the fall of 1931 for adult salmon bearing the marks. The Hoods Canal region is unique in that an examination of its many streams will provide a means of determining the degree of homing instinct of the pink salmon, that is, whether they return only to the stream in which they were hatched or whether they return to the streams of a general region. Preparations were made to mark pink-salmon fry in Snake Creek at Olive Cove, Alaska, in the spring of 1931.

FIGURE 5.—Shack used as a laboratory for pink salmon investigations at Olive Cove, Alaska

The marking experiments in Alaska will be supplemented by a racial analysis of the pink salmon in the various streams throughout the territory in which the fry are marked. During the summer of 1930 weekly samples were taken of the pink salmon running into Snake Creek at Olive Cove and into Anan Creek in Bradfield Canal.

The racial characteristics of the pink salmon composing these samples were analyzed biometrically for the purpose of determining:

(1) Differences in the racial characteristics of the salmon entering a given stream at different times during the run. This has an important bearing on the method of sampling the fish population in a stream. For example, if the population is homogeneous with respect to racial characteristics throughout the run, then a representative sample may be secured at any time during the run. However, if the population is not homogeneous throughout the run, then samples must be taken at regular intervals in order to secure a representative sample of the population.

(2) Differences in the racial characteristics of the pink-salmon population in Snake Creek and in Anan Creek.

The results from this part of the investigation are not as yet complete, hence it is not possible to draw any conclusions from them at the present time.

A list of all the important pink-salmon spawning streams in southeastern Alaska has been compiled. The streams in this list are classified according to the fishing districts in which they are found, and with the tabulation of each stream is included its name and location in degrees of latitude and longitude. Thus far only 45 streams have been surveyed in the territory. After a large number of streams have been surveyed, an analysis will be made of the data collected during the survey of each stream. It is hoped that this analysis will aid in determining some of the biological factors underlying the fluctuations in the size of the pink-salmon spawning populations in the streams.

There have been numerous requests from the packers in southeastern Alaska for an extension of the fishing season. They contend that the fishing regulations instituted in 1924 are protecting the late running salmon more than the early running salmon. They further contend that this unbalanced protection is tending to destroy the early runs and build up the later runs with the result that the bulk of the salmon are coming in later each year. In view of these contentions, an analysis is being made of the daily trap catches of pink salmon during the fishing seasons from 1908 to 1930 for the purpose of determining the variability in the time of appearance of the pink-salmon runs in southeastern Alaska both before and after the institution of the fishing regulations. The results from this investigation are not as yet complete.

Bristol Bay red-salmon investigation.—The scientific work in the Bristol Bay region during the past year has been devoted largely to a study of seasonal catch records and of the age at maturity of the red salmon of the Nushagak district. Alan C. Taft has conducted these investigations.

The analysis of the catch per unit of effort at Nushagak has shown that the total catch, when considered in relation to the changes in total effort, is a fair indication of abundance. The study of the catch per unit of effort has disclosed the same rate of decline up to 1921, which was found by Rich and Ball in their work on the total catch. The most serious decline was apparent in the period immediately following the war and undoubtedly was due to the intensive fishing during that time. Since 1921 there has been an upward trend in both the total catch and the catch per unit of effort. This, probably, has been due in part to the regulatory measures and closed periods instituted by the Bureau of Fisheries.

The catch per boat was also used in a study of the correlation between the annual catches at 4, 5, and 6 year intervals. The results were in keeping with those of Rich and Ball, who found a high correlation at 4-year intervals, but no significant positive correlation at 5 or 6 year intervals. The correlation at 4-year intervals is particularly marked in the series of cycles starting with 1903 and including 1907, 1911, 1915, 1919, 1923, and 1927. All of these years were distinctly below normal. This evidence of a high correlation at 4-year intervals will be useful in the formulation of regulations until an exact knowledge of the prevailing ages at maturity can be obtained by a scale study.

The preliminary scale work has shown that although 4-year fish are numerous, there is also a large number of 5-year fish in most of the annual samples. Work is now being continued which includes a study of the ages of fish from the two main rivers, the Nushagak and the Wood.

The field work during the past summer included an inspection of all the principal fishing areas in Bristol Bay. Trips were made up the Naknek and Ugashik Rivers as far as the weirs; and scale and migrant collections were made at Kakwok, 80 miles up the Nushagak. After the close of the commercial fishing season, a trip was made to Wood Lake for the purpose of collecting young salmon and visiting the spawning grounds.

Several of the principal spawning grounds of Illiamna Lake were inspected in the early part of August and in all cases there was a marked deficiency in spawning fish.

In addition to the scale collections made during the commercial fishing season, arrangements were made to have Frank Waskey collect scales from a series of 1,000 fish taken by natives on both the Nushagak and Wood Rivers.

Copper River red-salmon investigations.—During the past year the investigation of the red salmon of the Copper River has been continued by Seton H. Thompson, who devoted the greater part of the time to making a comprehensive collection of scales from fish taken by the commercial fishery and to studying the growth of the young salmon in Gulkana River, one of the important spawning grounds of the Copper River. Scales were also collected from adult fish spawning in the various tributaries. Many of the scales appear to be relatively easy to read, but others present irregularities that can not be interpreted with certainty until a very detailed study of the young fish has been made. Since each tributary and its lakes presents different environmental conditions, the study of the fresh-water growth of the scales is very complex. Five widely separated tributaries of this great river system are known to be important spawning grounds for the red salmon and many tributaries are still unexplored. A definite program has been outlined, and this work will be continued.

COLUMBIA RIVER SALMON

As in previous years the Bureau of Fisheries has cooperated with the Oregon Fish Commission in conducting salmon-marking experiments. One new experiment with fingerlings of a landlocked species, *Oncorhynchus kennerlyi*, was started. A previous experiment with this species resulted in a few recoveries which seemed to indicate that these landlocked fish could be induced to become sea-run and contribute to the commercial fishery. The returns from the first experiment were too few to be conclusive, and it seemed advisable to repeat the experiment.

Very few returns of marked fish were anticipated in 1930 but these few form a valuable part of the records obtained over a period of years.

ALASKA HERRING

In December, 1930, a scientific report was submitted to the bureau for publication by George A. Rounsefell who is in charge of the herring investigation, showing the changes in abundance that have

occurred in southeastern Alaska during the past several years. In this analysis a study was first made of the effect of the regulations that have been in force at various times, and of the effect on the catch of the improvements in the unit of fishing effort—the purse-seine boat. Southeastern Alaska was divided into 33 areas to correspond roughly to natural fishing grounds; and the abundance studied in the individual areas by means of the average daily catch per boat, the average number of deliveries per week per boat, and the average weekly catch per boat.

The report showed that a few of the areas were severely depleted, especially those in the central portion of Chatham Strait and those on the southern and eastern shores of Admiralty Island. Recommendations were made that these areas be closed to all seine fishing for at least five years. It was also recommended that the seining season be opened July 1 instead of June 1 in Stephens Passage and Lynn Canal; that the areas including Point Gardner, Saginaw Bay, and Keku Strait be closed to seining except during August; that the western shore of Kuiu Island from Point Kingsmill to Point Crowley be closed to seining during July; and that the weekly closed season for seining be extended to 48 hours along the southern shores of Baranof Island, from Red Bluff Bay to Crawfish Inlet. No recommendations were made for any of the other areas, including such productive fishing grounds as Icy Strait, Sitka Sound, Coronation and Warren Islands, and Noyes Island.

During the summer of 1930 intensive field work was carried on in southeastern Alaska by Edwin H. Dahlgren, temporary scientific assistant. In addition to the regular samples, racial data were obtained for the first time from the following localities: Cape Edgecumbe, Peril Strait, Kelp Bay, Warren Island, and Noyes Island. In southeastern Alaska large racial samples, including vertebral counts, are now available from 32 localities and small samples from about as many more. Altogether data are available on 10,000 specimens. The ages have been determined from the scales for over 7,000 of these specimens, and as soon as the age readings are completed an intensive racial analysis will be made.

As usual bureau representatives collected and preserved in formalin the annual series of samples for the fisheries at Prince William Sound, Afognak Island, Shearwater Bay, and Dutch Harbor.

Length data are now available for seven years, and age data for six years in Prince William Sound. These are now being carefully analyzed for fluctuations caused by dominant year classes and together with an analysis of the catch records, will soon be presented in a report on this district.

RAZOR CLAM OF ALASKA

Observations were continued by Seton H. Thompson, temporary assistant, on the razor-clam beds in the vicinity of Cordova, Alaska, during the 1930 season. With a slight increase in intensity of fishing, approximately the same pack was prepared in 1930 as in 1929. Both of these packs exceed those of the preceding three years in that district.

Although this fishery was slightly more intensive than in 1929, the age composition of the commercial catch reflects the rigid enforcement of the regulations and the cooperation of the canners, and indicates that the industry is on a stable basis. The clams varied from 3 to 13 years in age. Over 80 per cent of the clams were older than 6 years, and 86.48 per cent of all clams taken were mature. Of the total number taken 60 per cent had spawned more than once.

THE COCKLE

Material collected during the early razor-clam studies included shells of the cockle (*Cardium corbis*) from several localities on the Pacific coast ranging from Tillamook, Oreg., to Port Moller, Alaska. Although the amount of material was relatively small the homogenity of the samples and the uniformity of clam growth made it excellent material for growth studies and several interesting features have been presented in a report by Dr. F. W. Weymouth, of Stanford University, and Seton H. Thompson, temporary assistant.

(1) The ring method of age determination may be applied to this as well as to others previously studied.

(2) The growth of *Cardium* is characterized by great regularity as shown by the individual growth curves.

(3) The type of growth observed in the razor clam is also found in the cockle. In this form the relative growth rate falls throughout postlarval life as first noted by Minot in the guinea pig. The decline is orderly and regular and in most cases the growth curve can be accurately fitted from the formula $L=Be^{-ce^{-kt}}$ based on an exponential rate of decline of the relative growth rate.

(4) A comparison of growth in different localities shows the same relations as observed in the razor clam. The northern forms, in contrast to the southern, show a slower initial but more sustained growth, and reach the greater age and larger size.

ROGUE RIVER STEELHEAD TAGGING

During the summer of 1929 a tagging experiment dealing with the steelheads of the Rogue River was initiated in cooperation with the Oregon State Game Commission. This investigation has been under the supervision of J. A. Craig, and the work has as its definite object the solution of the problem of whether or not there are two separate races or self-propagating populations of steelheads in the Rogue River, one of which makes its upstream spawning migration during the summer and early fall and the other during the late fall and winter.

It seems logical to suppose that if there are two separate populations or races of steelheads in the Rogue River their spawning activities must be separated either by time or space. In order to discover data relating to the time of spawning and the extent of the spawning migrations of the steelhead in this stream adult upstream migrants were tagged near the mouth of the river during the summer and early fall of 1929 and the summer and fall of 1930. These fish are also being tagged during the winter of 1930-31.

In 1929, 677 steelheads were tagged and 25 were recovered. These recoveries indicate that the summer-run steelheads migrate to the upper reaches of the river and into the higher tributaries, and that they are present in these places in a spawning condition as late as March and April following the summer during which they ascended the stream.

At present the returns from the 1930 operations are by no means complete, and until data are secured on the recovery of winter-run fish no definite conclusions can be made.

CONSERVING FISH LIFE BY MEANS OF SCREENS AND LADDERS

The activities of Shirley Baker, engineer, and U. B. Gilroy, assistant, in conserving fish life by means of screens and ladders, consisted during 1930 of the following distinct undertakings:

(1) The continued operation of electric fish screens in the Yakima country, Washington, and in southern Oregon; (2) experimental work leading to the adoption of a simplified and improved type of electric fish screen and specification of this new type for operation during the irrigation season of 1931; (3) cooperative work with the power companies comprising experiments conducted at Green River hatchery of the division of fisheries, State of Washington, with a view to using the electric screen to lead upstream migrating salmon to a trap; (4) completion of the installation of the Ahtanum mechanical fish screen and its operation throughout the irrigation season; (5) the installation of large, concrete fish ladders at the Wapato and Sprague River Dams; (6) inspections and reports on conditions at several major power developments now under construction on important salmon rivers in the Northwest; (7) specification of fish-protective works required at certain hydroelectric power developments; (8) report on several types of mechanical fish screens and recommendations for screening several large water diversions in the State of Montana; (9) participation in the salmon-counting experiments conducted at Savage Rapids Dam on the Rogue River, Oreg.; (10) field work, designs, and reports on improvement to the water-supply system at the Bureau of Fisheries hatchery at Tishomingo, Okla., and for the proposed new hatchery at Butte Falls, Oreg.

MECHANICAL FISH SCREENS

From time to time during the course of this investigation we have been asked to examine and report on mechanical fish screens of various types. The variety of designs for such fish screens is very great, but nothing that has been called to our attention has been found to equal the mechanical revolving screen developed some years ago by the Oregon Game Commission and now approved and installed at a number of sites by that commission, by the Division of Fisheries of the State of Washington, and by our own bureau. A mechanical screen of this type was installed by the bureau in 1929 in the Ahtanum Canal, of the United States Indian Irrigation Service, Yakima, Wash., and is described in the previous report. Observation of the action of the fish at this installation substantiates the conclusion that a submerged orifice type of entrance is superior to an overfall in at-

tracting downstream migrating fish into a by-pass. This installation was 100 per cent effective in screening out the fish.

At the present time the bureau has under consideration the installation of such a mechanical screen in one of the Government diversions in Montana and is assisting the State of Michigan authorities by examination and reports covering the screening problems in various sections of that State.

ELECTRIC FISH SCREENS

In the work of this investigation the electric fish screen has been applied to three major problems confronting fish conservation, the device being employed: (1) As a stop or diverter to prevent the small, downstream migrating fish from entering irrigation and power diversions; (2) to stop or divert the mature, upstream migrating fish from entering tailrace waters at power houses; and (3) as a guide to lead upstream migrating fish to some particular location in the channel such as a counting weir or hatchery trap.

Patents on electric fish screens have been granted to H. T. Burkey, whose activities in the early development of the electric fish screen are related in the two previous reports. The type of screen now in use by the Bureau of Fisheries has departed widely from Mr. Burkey's original design and now conforms to the design developed and advocated by Professor McMillan.[3] The use of the old style grounded type of electric screen consisting of a row of suspended chain electrodes and a pipe, or similar ground element, laid in contact with the bed of the channel, has now been definitely abandoned in favor of the insulated type of screen consisting of a double row of large diameter pipe electrodes suspended into the water and entirely insulated from contact with the channel. Such a screen, due to the large diameter of the electrodes, eliminates the undesirably high voltage gradients which existed around the chain electrodes previously used, and the whole installation, being insulated from ground, is independent of the effects due to the conductivity of the channel material. Thus, the new screen is free from those defects due to the distorted and badly distributed electric field which, at certain locations, were unavoidable with screens of the grounded type.

Sunnyside electric screen.—The Sunnyside Canal, main diversion of the Yakima project, United States Reclamation Service, diverts water from the Yakima River, near Yakima, Wash.

The electric screen employed in this canal was of the grounded type, the spacing between chain electrodes being 24 inches and the ground element being a 2½-inch diameter galvanized pipe, laid flat on the bottom of the canal, parallel with the curtain of chain electrodes and 9 feet upstream from it. Electrification of the screen was effected with 60-cycle alternating current passed through the sign-flasher interrupter (2 to 20 interruptions per second) applied to the screen at voltages varying from 60 to 80 volts.

As commented on in the 1929 report operating conditions at this site were especially severe when high water caused increased velocities and the accumulation of débris at the screen, but results of the

3 Electric Fish Screen, by F. O. McMillan. Bulletin, U. S. Bureau of Fisheries, Vol. XLIV, 1928 (1929). Document No. 1042. Washington.

check of fish left stranded in the system in the fall of the year, together with observations made during the irrigation season lead to the conclusion that this screen has effected the saving of a good percentage of fish passing down river, and its use is held to be justified.

Wapato electric screen.—The Wapato Canal of the U.S. Indian Irrigation Service diverts water from the Yakima River about 3.5 miles upstream from Sunnyside Dam. Capacity of the canal is 1,800 second-feet. The 1930 diversion period extended from March 11 to November 22. For the major part of the irrigation season the amount of the diversion was close to the capacity of the ditch.

The screen employed here during the 1930 season was the same as described in the 1929 report. Although a good amount of water overflows the Wapato Dam at all times the depth of flow on the

FIGURE 6.—New electric screen at Wapato intake. See Figure 6, Fisheries document No. 1096, for a view of earlier installation

crest of the dam is shallow. On the other hand, the intake gates lift off the floor of the intake where the depth of water is approximately 20 feet, making the suction very great. This fact, coupled with the very high water velocities existing along the line of the electric screen, created a situation quite unfavorable to the successful by-passing of fish diverted by the screen.

To overcome, as much as possible, these undesirable conditions, the new screen planned for 1931 will be supported farther out in the forebay where water velocities are lower and will be of the improved insulated type with large electrodes energized with 60-cycle alternating current from a transformer.

A comprehensive check on the fish left stranded in the Wapato system was made at the end of the irrigation season, and additional information on this subject was secured when the principal laterals were dried up for cleaning in midsummer. Consideration of these findings and observations as to the presence of fish both in the river and in the ditch system indicates that in spite of the poor by-pass facilities and the unfavorably high velocities prevailing at the in-

take this electric screen has diverted a considerable number of fish and thereby justified its use.

Old Indian Canal electric screen.—As commented on in the 1929 report the Old Indian Canal which diverts water from the Yakima River and discharges it into lateral No. 1 of the Wapato Canal had, in its unscreened condition, permitted a large amount of fish to enter the Wapato system last year. To remedy this condition the Bureau of Fisheries installed an electric screen at the Old Indian Canal intake in the spring of 1930.

The screen employed was of the grounded type as has been previously described. Its location was just in front of the head gate and at a slight angle with it. At this location water is diverted into the canal by means of a low rock and brush dam. It was possible to maintain a favorable by-pass flow adjacent to the screen for the majority of the time.

If fish enter the Old Indian Canal they are discharged directly into lateral No. 1 of the Wapato Canal and are thus accounted for in the check of fish in the Wapato system. Water velocities at this location are not unreasonably high, and this factor along with the good by-pass facilities prevailing here argues well for the successful operation of this electric screen.

Tieton electric screen.—The Tieton Canal of the United States Reclamation Service diverts water from Tieton River at a point about 35 miles northwest of Yakima, Wash. The capacity of the canal is approximately 320 second-feet and this flow is maintained throughout the irrigation season. The screen is as described in the 1929 report, being of the grounded type consisting of a curtain of chain electrodes spaced 24 inches center to center and a ground element of anchor chain, all being located outside of the canal head gates.

Check of fish left stranded in the Tieton system together with observations regarding fish conditions along the Tieton River above and below the head gate and in the canal itself indicates satisfactory functioning of the electric screen at this installation.

Naches power house electric screen.—In the early summer of 1930 the Pacific Power & Light Co. electrified the screen which they had installed the previous year under the supervision of the bureau. This installation is located at the head of the Wapatox Canal, which diverts water from the Naches River for use at the Naches and the Drop power plants near Yakima, Wash. The ditch has a capacity of about 600 second-feet. The screen is of the grounded type, consisting of a curtain of chains and a ground element of pipe laid in contact with the bed of the concrete-lined canal. This screen is located a short distance down the canal from the head gates and adjacent to the spillway which, throughout the spring and summer months, offers an excellent by-pass channel for return of fish to the river.

Observation of fish conditions in the Naches River in the vicinity of this diversion and inspections of the canal itself from time to time during the summer indicated the high efficiency of this screen. During the period that an adequate by-pass was maintained, which was during the principal migration season, it is estimated that at least 90 per cent of the fish entering the Wapatox Canal were diverted through the by-pass by the electric screen.

Gold Ray intake screen.—As detailed in the 1929 report this electric screen of the insulated type was installed last September in the intake at the Gold Ray power plant, Rogue River, Oreg. This screen consists of a double row of 6-inch diameter pipe electrodes, spaced 6 feet between rows, the pipes being 4 feet center to center in rows.

The screen was installed again in the spring of 1930 and operated until the Gold Ray plant shut down for a period to allow the construction of a new trash rack and head-works structure. The screen was reelectrified late in the summer and continued in operation until late in the fall. The power plant was shut down during the peak of the downstream migration, and, therefore, conclusions as to the effectiveness of the screen are unwarranted.

Gold Ray tailrace screen.—The purpose of this screen installation is to prevent the upstream migrant salmon and steelhead from entering the tailrace waters at Gold Ray power plant and to divert them in fresh condition into the main channel of the river leading to the fish ladders over the dam. This screen, which was of the grounded type described in detail in the 1929 report, continued its highly effective operation until May 8, 1930, at which time the power plant was shut down for the installation of the new head-works structure referred to above.

Soon after the screen was put in operation it was observed that a number of Chinook salmon and steelhead were penetrating the screen and that some others were being paralyzed in their passage over the ground pipe. Accordingly, the grounded type of installation was abandoned in favor of the insulated screen. The new screen was electrified July 17. It consists of a double row of 6-inch diameter pipe electrodes of No. 20 gage galvanized iron which are suspended in the water from supporting cables. Spacing of the pipes is 4 feet center to center in rows, and the rows are spaced 6 feet apart. The lower end of each electrode is fitted with a hemispherical cap of galvanized iron and filled with concrete to provide the necessary weight to hold the electrode vertically in the water. The screen is energized with 60-cycle alternating current passed through the special transformer.

Prior to the electrification of the new screen the tailrace was cleared of fish and since that time none has been found above the screen. The conditions for observation of the action of the screen are excellent and hundreds of salmon and steelhead have been seen to encounter the screen and be diverted without injury into the main channel. The action of this screen is positive, and its continued operation is held to be a factor of major importance in the conservation of fish on Rogue River.

Experiments with electric screens for use at intakes.—Seeking improvement and simplification of this type of electric screen the experimental field work started in 1929 was continued in the 1930 season. This year the experimental installations were set up at Old Indian Canal on the Yakima River, in the sluiceway at the Gold Ray power plant, and at the Fort Klamath hatchery of the Oregon Game Commission. The Yakima tests were conducted by Professor McMillan and Mr. Wagner. The fish used were Chinook salmon fingerlings about 4 inches long. These tests demonstrated: (1) The

superiority of the insulated type of screen over the grounded type, (2) the superiority of large diameter electrodes over the chain electrodes as previously employed, (3) the effectiveness of ordinary 60-cycle alternating current without resort to interruption or other modification, and (4) they indicated in general the electrode spacing and screen voltages required for effective operation of the screen.

In Oregon the experimental work was started in the sluiceway at Gold Ray power plant and later the installation was moved to the Fort Klamath hatchery where facilities were better as regards visibility, control of water, and the availability of fish for use in the experiments. At the former location the fish used were steelhead fingerlings and at Fort Klamath a total of about 2,000 brook trout averaging about 2 inches long were employed. All of these were fine healthy fish.

The experiments showed the screen to be most effective when the electrode spacing was 4 feet center to center in rows and 6 feet between rows, and when the potential was maintained at about 55 volts.

The experimental work of the 1930 season has resulted in the specification of new and improved electric screens for use in 1931.

Kvichak electric screen.—Based upon success of the Gold Ray tailrace screen in stopping upstream migrating salmon and diverting them to the fish ladders at the dam, the bureau this season sought to employ the electric screen in its salmon-counting operation on the Kvichak River, Alaska. The structure consisted of the ordinary type of wooden rack of picket construction equipped with counting gates and carried out from each shore through the shallower depths. Piles were driven across the main channel to support the electric screen, the alignment of which was in the shape of a V with the apex 200 feet downstream, from the line of the racks. Total length of the electric screen was 755 feet including a 40-foot boat passage at midstream. Design of this electric screen was based on the Gold Ray tailrace installation. It was of the grounded type, consisting of a curtain of chain electrodes and a ground element of pipe laid in contact with the bed of the stream. For energizing the screen the Bureau of Fisheries installed a power unit on shore consisting of a 9-kilowatt generator, supplying 60-cycle alternating current, driven by a 15-horsepower gasoline engine. Current was supplied to the screen at a potential ranging from 60 to 80 volts.

In general, the installation stopped the upstream migrating salmon but failed in its purpose which was to lead or divert these fish to the counting gates located in the rack structures extending out from each shore. Some salmon succeeded in fighting their way through the electric screen which extended over about three-quarters of the river channel but several hundred thousand of them—constituting the greater portion of the run—dropped back downstream after encountering the electrified water and remained there, milling around, and making no further attempt to pass upstream. The reason for the failure of this screen is not known. One unfavorable factor was the absence of definite water currents to attract the salmon to the counting gates. This was because the obstruction offered by the rack structure caused the tendency of the flow at the rack to be offshore along the upstream line of the rack and toward the great

open section of the river in which the electric screen was installed. Over the major portion of the screen section the channel depth was about 15 feet and water currents were quite swift.

Experimental electric screen at Green River.—Seeking to develop the electric screen for use in guiding fish to some particular point in the channel the bureau in cooperation with the Northwestern Electric Light & Power Association installed an experimental electric screen at the Green River hatchery of the Washington Division of Fisheries this summer. The facilities and services of the hatchery staff were kindly offered by that body. The location afforded fine visibility and opportunity to experiment on large runs of fish.

The site chosen was favorably located for obtaining a check on the efficiency of the screens inasmuch as the installation was made directly downstream from the wooden rack and trap structure built across the river to obtain fish for spawning purposes. Thus, fish that might penetrate the electric screen were caught against the wooden rack; many thousand Chinook, silver, and dog salmon encountered the screen during the season of its operation. The insulated type of screen was employed, consisting of a double row of 6-inch diameter pipe electrodes suspended in the water from supporting cables. Best results were found to be obtained when the spacing was 4 feet center to center between electrodes in rows, and with the rows 6 feet apart.

The screen was electrified with 60-cycle alternating current supplied from a transformer. For the purpose of studying the guide features of the screen a pool of timber construction resembling the entrance pool to a fish ladder was built at the end of the electric screen on the east bank and water was supplied to this pool to produce an overfall for attracting fish. In addition to this a small creek joins the river from the east about 50 feet downstream from the electric screen. Some salmon have always run this creek and the Green River hatchery maintains a rack in this creek about one-quarter mile above its mouth. It was thought that fish running in Green River, upon encountering the electric screen, might be diverted up the creek.

When electrified at 80 volts the screen effectively stopped the upstream migrating salmon, but was found to be killing a number of downstream migrating fish. When the potential was lowered to 60 or 65 volts the screen was still found to be effective against the upstream migrants and at the same time downstream migrants were no longer affected. The effectiveness of the screen in holding upstream migrating salmon without injury was at once evident; in fact, in order to get fish for spawning purposes it was necessary to deenergize the screen, as practically no fish were able to penetrate the electrified water.

Results obtained, considering the screen as a guide, were held to be very encouraging despite the fact that the presence of the electric screen in the river did not cause any material increase in the number of fish being taken at the creek rack. Reasons for lack of increase in the creek run over previous years are believed to be due to the instinct of the fish to remain in the Green River water rather than to pass into the creek, and physical conditions at the mouth of the creek where the water was deep and there was almost no current. On the

other hand the river bed in the vicinity of the screen consisted of gravel bars overrun by shallow water, which was attractive to the fish. A large number were seen to make their nests and spawn here.

At times as many as 15 to 20 salmon would be found in the timber pool located at the end of the electric screen. This evidence of the action of the screen in leading even a small number of fish to the pool is considered quite encouraging as physical conditions at its entrance were not entirely favorable.

FISH LADDERS

The activities of 1930 in the fish-ladder field include: (1) The building of new, modern concrete fish ladders at two Government projects, these being the Wapato Dam on the Yakima River and the Sprague River Dam in Oregon; (2) specification and supervision of construction on alteration of fish ladder at Gold Ray power plant on the Rogue River; (3) inspection and supervision of progress of

FIGURE 7.—Wapato fish ladder. View looking toward west shore showing side entrance pool and shear boom raft at top of dam

construction of the fish ladders specified for the Rock Island development; and (4) specification of required fish-protective devices for certain power applications submitted to the Federal Power Commission.

Wapato fish ladder.—The success of the Sunnyside fish ladder built by the U. S. Bureau of Fisheries last year was immediate, and this installation emphasized the need of a similar structure at the Wapato Dam, of the U. S. Indian Irrigation Service, located about 3½ miles up the Yakima River from the Sunnyside Dam. Accordingly, the aid of the Department of the Interior was solicited and funds secured from it for the construction of the ladder. Design of the Wapato ladder followed closely the features of the Sunnyside installation. The U. S. Reclamation Service showed a fine spirit of cooperation in making available to us the services of their construction organization. The ladder has been installed in the east channel of the river at the Wapato diversion. Crest length of the dam is

400 feet. The ladder is located about 100 feet out from the east shore, and has a net height of about 10 feet. The construction work was started late in October and water was admitted to the completed ladder about a month later. A fine piece of construction was secured.

During the fall the Washington State Division of Fisheries constructed a concrete fish ladder at the Prosser Dam at the lower end of the Yakima River. The completion of the Prosser, Sunnyside, and Wapato fish ladders now opens the Yakima River and its tributaries for many miles to the ascending fish.

Sprague River fish ladder.—Conditions at the Sprague River Dam of the U. S. Indian Irrigation Service near Chiloquin, Oreg., have been set forth in the 1929 report, together with an account of the preliminary work done here. Last summer the bureau's engineers prepared designs and specifications for the required fish ladder and early in September a contract was let for this construction. The work was completed late in the fall. The design follows the principles displayed in the Sunnyside ladder and adapts itself to the particular features of the dam and sluiceway construction at Sprague River. This dam is 11.3 feet high.

NEW AND PROPOSED POWER PROJECTS

An important activity falling within the province of this investigation has been in connection with a number of power developments now under construction in the Northwest or pending license by the Federal Power Commission.

The major developments investigated and reported on in 1930 are as follows:

(1) Rock Island development of Washington Electric Co. on the Columbia River, Wash.

(2) Kettle Falls development of Washington Water Power Co. on the Columbia River, Wash.

(3) Flathead development of Montana Power Co. on Flathead River, Mont.

(4) Ariel development of Inland Power & Light Co. on Lewis River, Wash.

(5) Cascade Locks project (Hobson application) proposed for Columbia River at Cascade Locks.

(6) North River development of Western Washington Electric Light & Power Co. on North River, Wash.

At the Rock Island development, remarkable progress has been made. The end of 1930 saw the completion of the power house and spillway dam in the east channel of the river. By this time also, the high fish ladder at the power house had been virtually completed, lacking only fitting up with entrance gates and the installation of stop-log partitions between the pools. This ladder which is 630 feet long is of heavy reinforced concrete construction. The pools are 20 feet wide by 10 feet long and the grade is 1 to 10. A very fine piece of construction work has been done.

Concerning the Kettle Falls development—a project of major size proposed for the Columbia River—examinations were made and conference held with engineers of the power company and with the interested State organizations. This led to the specification of the

requirements for fish protection as held to be necessary by the State officials and the Bureau of Fisheries. These specifications have been presented by the Commissioner of Fisheries to the Federal Power Commission for incorporation in the project license if and when issued.

The Ariel development, which is planned for an ultimate capacity of 180,000 kilowatts was visited several times during the summer and fall of 1930. The dam is 180 feet high. Here a very comprehensive scheme of fish protection has been carried out under the supervision of the Division of Fisheries, State of Washington. The plan involves the mechanical handling, ripening, spawning, and rearing of fish on a large scale. Much that is novel has been introduced. The work reflects careful planning and supervision. The fish protective works being provided here will cost approximately one-third of a million dollars.

The North River power project proposes the development of 37,500 horsepower by the building of a concrete dam 112 feet high on the North River, in Pacific County, Wash. The plan for fish protection, as worked out in cooperation with the Division of Fisheries, State of Washington, proposes mechanical handling of both upstream and downstream migrating salmon. Conditions at this site lend themselves to such a procedure.

The important problem of the practicability of handling migrating salmon mechanically at high dams will go on trial at North River, and the work is expected to attract the interest of all concerned with fish conservation.

INVESTIGATIONS IN THE INTEREST OF FISH CULTURE

Investigations of direct interest to fish culture under the direction of Dr. H. S. Davis, in charge, aquicultural investigations, have been extended during the past year. Studies under the general projects of pond-fish culture and trout culture have been continued and have developed normally, producing additional results of practical value. Experimental propagation of largemouth and smallmouth black bass, crappie, and bluegill sunfishes was continued at Fairport, Iowa, and theoretical limnological studies in both laboratory and field were conducted.

A brief survey of stream conditions in southeastern Nebraska was made, and field experiments on increased fish production in the Upper Mississippi Wild Life and Fish Refuge have resulted in a comprehensive program of fish culture in that area.

Feeding and breeding experiments on trout were continued at the Pittsford (Vt.) station, and stocking experiments with black-spotted trout and Montana grayling were undertaken in the vicinity of the station. Studies of the diseases of fish, particularly trout, were continued, and an additional project embracing a study of the epidemic of sea herring in Maine was undertaken.

POND-FISH CULTURE

Investigations at the Fairport (Iowa) station were carried on under the immediate direction of Dr. A. H. Wiebe. This station serves as headquarters for investigations relating to pond culture,

and it is the intention to conduct the more fundamental investigations here where adequate laboratory facilities are available. The facilities for pond work have been greatly increased during the past summer by the construction of additional ponds with a total area of about 8 acres. Several of the old ponds have been repaired or remodeled and a number of additional concrete pools built for experimental work on the effect of fertilizers. Well water is now available for several of the smaller ponds which will materially increase their value for experimental work.

Propagation of black bass.—The season of 1930 was a very successful one, the number of fish produced being much larger than in any previous year. The methods used in the propagation of bass were much the same as last year with some modifications in details which have been adopted as the result of experience. Golden shiners (*Notemigonus crysoleucas*) were used for forage fish, the ponds being stocked with adults early in the season at the rate of about 800 fish per acre. Approximately the same number of shiners were used in both brood and nursery ponds but those placed in the brood ponds averaged considerably larger.

During the spring and early summer most of the ponds were fertilized with a mixture of equal parts superphosphate and dry sheep manure. A small amount of the mixture was applied every 10 days, the total for the season being at the rate of 600 pounds per acre.

Three ponds were used as brood ponds, most of the fry being removed to nursery ponds shortly after they rose from the nests. Pond D 5, stocked with 7 male and 17 female largemouth bass, produced an average of approximately 8,000 fry to each female. These are the oldest bass at the station and average about 2 pounds in weight.

All new additions to the brood stock consist of fish which have been reared in the hatchery ponds. That such fish are equal if not superior to wild fish for this purpose is shown by the production of fry in pond D 9, which was stocked with forty-four 4-year-old fish (13 males, 21 females) that had been reared at the station. Although these fish weighed slightly less than a pound, the average production of fry was 7,134 per female.

The total production of largemouth fingerlings during the season of 1930 was 76,400, an average of approximately 9,670 per acre. Several ponds averaged over 10,000 fingerlings per acre and in one pond, slightly over ½ acre in area, the production was at the rate of 24,339 per acre. This pond was heavily overstocked with fry; and the fingerlings when removed were considerably smaller than those from the other ponds, indicating a deficiency of food. It is probable that not over 10,000 to 15,000 fingerlings per acre can be reared successfully without resorting to artificial feeding.

For the past three years a small stock of adult smallmouth bass has been maintained at the station. In view of the fact that conditions here are quite different from those usually thought to be essential for the successful propagation of this species, the fish have done remarkably well. A pond slightly less than 1 acre in area, which was used as a combined brood and rearing pond, showed a fingerling production of 10,615 per acre.

Propagation of crappie and bluegill sunfish.—The production of fingerling crappie was relatively small, since only two small ponds

were available for these fish. One pond stocked with crappie and blackhead minnows for forage produced 3,108 two-inch fingerlings, which was at the rate of 13,861 per acre. In another pond (D 2) which was stocked with adult crappie and bluegill sunfish the production of crappie was at the rate of 13,988 per acre. In addition, this pond produced 25,920 bluegills averaging about 1½ inches in length. This was at the rate of 92,800 per acre. The total production of crappie and bluegill sunfish was approximately 106,000 fingerlings per acre. The results from this pond are in accord with those of previous years in indicating that crappie and bluegills make a very satisfactory combination, which works out to the mutual advantage of both species.

Cooperative experiments.—In accordance with our program of cooperative experiments at several hatcheries in different localities, arrangements have been made to operate several ponds at the Tupelo (Miss.) station on an experimental basis. During the season of 1931 these ponds will be stocked with bass and fertilized in the same way as at Fairport. Conditions at the Tupelo station are very different from those at Fairport, and these experiments will enable us to determine if the methods developed at Fairport will be equally successful at southern stations or whether they will require considerable modification.

LIMNOLOGICAL INVESTIGATIONS

Some preliminary observations by Doctor Wiebe during the summers of 1928 and 1929 indicated that the changes in the amount of dissolved oxygen and alkalinity that occur in a pond within a 24-hour period may be as large, if not larger, than the seasonal changes when the observations are taken regularly at the same time each day. For this reason it was decided to make a series of tests to determine the extent in the diurnal variations in dissolved oxygen, alkalinity, and in some instances ammonia nitrogen. These observations show that very marked changes in the actual amount of dissolved oxygen and in phenolphthalein alkalinity may occur within 24 hours and that the extent of these variations are determined by the abundance of the algæ. It appears that the algæ can utilize all of the CO_2 present as bicarbonate as well as some of the CO_2 of the normal carbonate.

A brief survey of the Blue River system in Nebraska was undertaken by Dr. A. H. Wiebe and H. L. Canfield during July, 1930. The purpose of the survey was to determine what species of game fish might be successfully introduced into the streams that constitute the river system. The streams were found to be adapted to both species of black bass and to the bluegill sunfish, although none of these fish are found in the Blue River or its tributaries at the present time. The principal fish taken during the survey were the channel catfish, white crappie, green sunfish, carp, buffalo, and bullheads.

UPPER MISSISSIPPI WILD LIFE AND FISH REFUGE

The work in the Upper Mississippi Wild Life and Fish Refuge was continued along the same lines as in 1929 under the immediate direction of E. W. Surber. Detailed quantitative biological studies of five sloughs in the bottoms of the Mississippi River which were begun in the spring of 1929 were continued during the winter and

summer of 1930. Collections of the plankton and of the bottom and weed-dwelling organisms were made at 2-week intervals throughout this time. At the same time determinations were made of the chemical conditions.

The observations revealed that the sloughs differ widely in the production of natural food, that the bottom and weed populations are apparently composed of few species but large numbers of individuals, and that the character of the bottom of a slough can be used in predicting the quantity and density of the food it contains. Gas analyses of samples taken in winter beneath the ice showed that the oxygen supply of the sloughs investigated was exhausted by the end of January. For this reason it will be impossible to hold fish

FIGURE 8.—Limnological investigations in the sloughs of the Upper Mississippi Wild Life and Fish Refuge

in the sloughs during the winter and holding ponds for the brood fish must be provided elsewhere. Complete analysis of the data accumulated in these studies will not be possible for several months.

A few of the sloughs have no direct connection with the river, but the great majority have one or more natural channels which connect with the river except at low stages. These channels must be closed by screens when the sloughs are used for the propagation of bass or other game fishes. It is also necessary to remove the larger aquatic plants and the bushes lining the shore so that the entire slough can be seined.

The first serious attempt to propagate largemouth bass in the sloughs was made during the season of 1930. A number of sloughs, which had been selected for the purpose, were cleared; and screens constructed across any connection with the river. After the enemy fish had been removed the sloughs were stocked with forage minnows

and later with bass fry. Unfortunately shortly after the sloughs were stocked with bass there was an unusually high June flood, which rose above the screens and allowed the fish to escape. This occurred in five of the eight sloughs which had been stocked. The remaining three sloughs all showed a good production of fingerling bass.

One slough with an area of approximately 4 acres was stocked with 20,800 bass fry on June 15. When seined September 15–17, there were 10,538 fingerlings removed, a survival of approximately 50 per cent. Another slough known as pond No. 2 with an area of 1.5 acres was stocked with 5,180 fry on June 22. The slough was seined September 19, and 3,691 fry averaging 4⅜ inches long were recovered. This is a survival of approximately 71 per cent which is by far the highest rate of survival obtained in any of our experimental work. The third slough, area 1.3 acres, was used as a brood pond so the number of fry in the pond is unknown. This pond was seined August 20–22 and 11,422 fingerlings removed. This is at the rate of 8,786 fingerlings per acre which compares favorably with the production obtained in the ponds at Fairport.

Although on account of the unusual flood conditions the total production of bass fingerlings fell short of expectations, it is evident that in ordinary seasons these sloughs can be made to produce fully as many fish as the average hatchery pond.

Since the control of aquatic vegetation is essential to the successful utilization of the sloughs for the production of game fish, considerable attention has been devoted to this problem. Experiments with a sodium arsenite weed killer by Mr. Surber indicate that treatment of the fishponds with this chemical may furnish a solution of the problem. From the fish-cultural standpoint this chemical has a great advantage over copper sulphate, which has been used to some extent for this purpose, in that it affects the algæ less than the higher plants and is not nearly so toxic to fish.

In the experimental work in the sloughs used as fishponds, dilutions varying from 1 to 1.7 parts per million—depending on the density of the vegetation—of arsenious oxide have been used with success. It was found that the treatment did not directly destroy the abunuant plankton organisms, either plant or animal. Furthermore, no serious effects have been produced on the abundance of bottom organisms and Entomostraca except in some instances where the numbers of organisms dependent on the larger aquatic plants have been reduced as was to be expected. No evidence was obtained in these experiments that concentrations of arsenious oxide up to 3.5 parts per million were toxic to fish in the slightest degree. The only mortality that occurred was caused by lack of oxygen which, of course, can be avoided by beginning the treatment in the spring before the vegetation has become unduly abundant.

Experiments at the Fairport station by Dr. A. H. Wiebe have shown that bass, bluegills, and crappie are not appreciably affected in aquaria by concentrations of As_2O_3 as high as 7 parts per million. It is evident, therefore, that there is no danger of the fish being seriously injured by the sodium arsenite treatment. Experiments are now being made to determine the effect of arsenic on some of the more common food organisms of fish.

In preparation for the experiments during the summer of 1931, a large stock of brood bass has been accumulated and is being held over the winter in a spring-fed pond at Trempealeau, Wis. In the spring these fish will be transferred to suitable ponds in which they will be allowed to spawn, and the resulting fry will be used for stocking sloughs which have been put in readiness to receive them.

TROUT CULTURE

Investigations relating to trout culture were carried on at the Pittsford (Vt.) station under the immediate supervision of Russell F. Lord. As in previous years, these investigations included feeding experiments with various rations and a systematic plan of selective breeding. Studies of the food and movements of trout in Vermont streams were also made, and it is planned to increase the scope of these investigations in the near future.

A number of additional rearing ponds were constructed during the year which will considerably increase the capacity of the station. The available supply of spring water is now being utilized to its full capacity, and, for this reason, no further increase in the number of rearing ponds will be possible.

Feeding experiments.—The feeding experiments during the summer of 1930 were conducted almost entirely with fingerling brook trout. Owing to heavy losses among the yearling trout from furunculosis during the previous winter, only a few fish of this age were available for experimental work. As in previous years, each lot containing 1,500 fingerlings occupied an entire hatchery trough through the summer. The fish were carried on experimental diets from April 16 to September 3, inclusive.

With very few exceptions the fish made a more rapid growth than in previous years on comparable diets and the mortality was relatively low. This was probably largely due to the fact that the fish used in the experiments were from eggs produced at the station from selected stock. In previous experiments the fish were hatched from eggs obtained from outside sources.

The most striking feature of the experiments was the results obtained with the use of dried salmon eggs. These when ground into a fine meal make an excellent trout food, although, like all dry foods, they should always be fed in combination with fresh meat. In comparison with the controls fed straight beef liver the fish on a ration composed of equal parts beef liver and dry salmon eggs averaged one-third larger and the mortality was considerably less. The fish fed salmon eggs were exceptionally lively and vigorous and showed the brilliant coloration of wild trout of the same age. This latter character is a very striking one, the pink fins and iridescent sides appearing in marked contrast to the dull colors of fish on other diets.

As would naturally be expected, yearlings on a salmon-egg ration developed even brighter colors than the fingerlings. After being kept on such a diet for several weeks they could not be distinguished from wild fish.

The bright colors of fish fed a salmon-egg ration opens up great possibilities. A number of States have adopted the policy of rearing all trout to legal size before they are liberated, and there is no doubt that this practice will soon be followed in other sections. The most serious drawback to this practice is the fact that hatchery-fed fish invariably have a much duller coloration than wild fish and, therefore, can be readily recognized by the discriminating angler. This difficulty can be eliminated by feeding the fish a ration rich in salmon eggs for a short time before they are to be distributed. Not only do they quickly assume the bright colors of wild fish but they also show remarkable vigor and resistance to disease. It thus becomes possible to artificially rear fish that are indistinguishable from those which have spent their lives in open waters.

Steam-dried menhaden meal also gave good results when fed in combination with beef liver and was found to be superior to the flame-dried product. It is becoming increasingly evident in these experiments that properly prepared fish meals and dried milks form a valuable addition to the diet of trout. Not only do the fish do fully as well, or even better than on a straight meat diet, but there is also a considerable saving in the cost of the food. At current prices the cost of the food required to raise trout to a certain size on a diet containing a large percentage of dry salmon eggs or menhaden meal is about 40 per cent less than when they are fed straight beef liver.

A set of experiments was also run to determine the relative value of pig melts as a trout food. Owing to its low price this product is being fed in considerable quantities at a number of hatcheries. It was found that pig melts, either alone or in combination with other meals, are considerably inferior to beef liver as a growth producer but are superior to beef melts which are also fed at some hatcheries.

The experiments showed that in general the rations which produced the most rapid growth were also the most economical even though the actual cost of the ration might be somewhat higher than that of the poorer rations. This is due to the fact that with the poorer rations a larger amount of food is required to produce an equal amount of fish flesh. For instance, with the salmon egg rations about 3 pounds of food were required to produce 1 pound of fish, with straight beef liver about 4 pounds of food were required to produce the same amount of fish, while the pig melts it was necessary to feed approximately 6 pounds of meat to produce the same result.

Breeding experiments.—The work in selective breeding was continued along the same lines as in previous years. Each season a number of select fish are mated and the progeny of each pair reared separately during the following summer. In selecting these fish special emphasis is placed on rapid growth, vigor, fecundity, body symmetry, and coloration. Since it is obviously impossible to rear the progeny of each pair to maturity separately only the young which excel in the characteristics noted above are retained for experiment during the second season. In this way it is the confident expectation that within a few years a stock of exceptionally vigorous and rapidly growing fish will be built up.

During the fall of 1930 eggs were taken from 45 pairs of selected fish, and the young are now being held in separate compartments

under as nearly identical conditions as possible. In accordance with the program outlined above the inferior lots will be discarded later in the season.

While the breeding work is still in its infancy it is already evident that the results will be of great practical value. Probably the most notable result up to the present time is the demonstration that the time at which trout spawn is determined primarily by heredity, although evidently influenced to some extent by environmental conditions. At the Pittsford station there are several strains of trout from different sources and these all showed marked difference in the date on which they are ready to spawn. This was shown in a striking manner in one pond containing two strains of brook trout. When examined on October 28 practically all of the fish of one strain were ready to spawn while the other strain showed no indications of being ripe.

Moreover, it appears that the relative time of spawning is constant from year to year. The earliest fish to spawn in 1929 were also the first to spawn in 1930. In 1929 the eggs were taken on October 29 while in the following year the fish were ready to spawn on October 25. The advance in the spawning date in 1930 is in accord with the general belief that older fish usually spawn somewhat earlier than those spawning for the first time.

Another indication that the spawning date is determined primarily by heredity is the fact that all of the progeny of a single pair of fish are usually ready to spawn at approximately the same time. This is in striking contrast to the condition in mixed lots where the spawning period almost invariably extends over several weeks.

It is evident that this is a matter of considerable practical importance since it is possible by selection to develop a strain of fish with a short spawning season which will result in a considerable saving in labor. It will also be possible to develop early or late spawning strains as desired. Furthermore, the eggs should be of better quality, since there is considerable evidence that fish which have been closely confined for some time produce inferior eggs.

Stocking experiments.—During the summer and fall of 1930 plantings of fingerling black-spotted trout and Montana graylings were made in several streams in Vermont in order to determine if these two species will thrive in eastern waters. Contrary to the general belief it has been found, as pointed out in previous reports, that both the black-spotted trout and the grayling do well at the Pittsford hatchery so it is evident that the climatic conditions are favorable for both species. The black-spotted trout occurs naturally under a wide range of conditions in the West, and it is not impossible that they may be found better adapted to certain eastern waters than the native brook trout.

During the past two years several hundred rainbow and steelhead trout have been tagged and liberated in Vermont streams. These were all adult fish which had been reared at the Pittsford station. So far only a small percentage of the tags have been accounted for, but enough have been returned to indicate that the fish have lived up to their reputation as having a much more roving disposition than the brook trout.

FISH DISEASES

Herring disease.—During July, 1930, Dr. H. S. Davis in company with the State inspector and officials of the Federal Food and Drug Administration visited some of the more important fishing centers on the coast of Maine in an effort to obtain first-hand information regarding the so-called herring disease. This disease first became prevalent in 1929 and has been the cause of considerable anxiety to the herring and sardine industry since that time.

It was found that the disease was apparently fully as prevalent in 1930 as during the previous summer, although at the time it appeared to be declining in severity. Later in the season, however, conditions again became worse; and, at the urgent request of the sardine packers, the bureau has undertaken a thorough investigation of the disease. This investigation is being conducted in cooperation with the State of Maine, which is defraying most of the expenses. A laboratory has been established at Eastport, Me., and provided with the necessary equipment for investigating all phases of the disease. A sardine boat has been chartered by the State, and this will enable the investigators to visit the weirs in the vicinity of Eastport and collect their own fish if necessary.

George E. Daniel with the assistance of several of the State sardine inspectors is now actively engaged in a study of the disease. He will be joined later in the season by Frederic F. Fish.

The disease is evidently due to a microorganism belonging to the obscure genus known as Ichthyosporidium or Ichthyophonus. Although several different parasites belonging to the genus have been described, practically nothing is known regarding the organisms or their life history. Even the affinities of the genus are very uncertain. The parasites were originally thought to belong to the Haplosporidia, a group of protozoa, but it now appears more probable that they are in reality more closely related to some of the lower fungi (Chytridiniæ). The appearance of the parasites in the herring support the latter theory.

The parasite occurs in all parts of the body but is especially abundant in the muscles and liver. The development of the parasite is apparently not affected by seasonal changes since the appearance of the diseased fish is identical whether taken during the winter or in the summer. Furthermore, preliminary studies at Eastport indicate that fully as large a percentage of the fish taken in winter are infected as during the summer.

Trout diseases.—Studies on furunculosis and the gill disease have been continued by Doctor Davis at the Pittsford station. A severe outbreak of furunculosis provided an opportunity for additional studies on this disease, which, everything considered, is probably the most serious infection known to occur in trout. Particular attention was paid to the pathology of the disease, which previously had received relatively little attention from investigators. Furunculosis has appeared at several of the bureau's hatcheries during the last year or two, and it is evident that the disease is yearly becoming more prevalent. Unless great precautions are taken to prevent its spread, it will soon become as common as in Europe.

OYSTER INVESTIGATIONS

Oyster investigations during 1930 were continued under the direction of Dr. Paul S. Galtsoff along the following lines of research: Experimental studies in oyster culture, studies of the causes of the decline of the oyster industry and of the mortality of oysters, analysis of the oyster bottoms, and development of the methods of controlling the enemies of the oyster.

Field and laboratory research work was carried out both along the Atlantic and the Pacific coasts of the United States and, at the request of the Territorial government of Hawaii, was extended to the Hawaiian Archipelago.

SETTING, METAMORPHOSIS, AND DISTRIBUTION OF OYSTERS

During the past summer the investigations of the physical, chemical, and cytological aspects of the setting of the oyster have been completed by H. F. Prytherch. These studies have shown that copper is the specific factor of greatest importance in the attachment, survival, and distribution of this marine organism. Copper is brought down to the inshore coastal areas either by the rivers or by the flow from underground channels and examination of several fresh-water streams in Connecticut has shown that it is present in these waters in amounts varying from 0.1 to 1.5 parts per million and is present in greatest amounts after periods of heavy precipitation.

Since the setting of the oyster larva may be induced by solutions containing as little as 1 part copper to 50,000,000 parts of sea water, it is not surprising to find that there is a definite relation between the distribution of oyster beds and prolific seed producing areas, and the flow of fresh water containing copper into these coastal regions. In Milford Harbor, Conn., setting takes place at low slack water when copper was found to be present in amounts varying from 0.1 to 0.6 part per million and did not occur at other stages of the tide when it was impossible to find measurable amounts of this metal. Traces of copper were found to be necessary also for the metamorphosis of the larva into a spat and this served to bring about the breaking up of the pigment spots and the release of numerous deeply colored cells of which they are formed. In the absence of copper the attached larva failed to metamorphose or grow and lived for a period of 8 to 14 days. Those receiving copper stimulation after attachment became transformed into spat in a few hours and grew rapidly under the same conditions as those used for the retarded individuals.

The salinity of the water was found to have a pronounced effect upon the velocity of the setting reaction or length of time required for attachment. The optimum condition for setting was found to be in salinities from 15 to 20 parts per thousand, while above or below this salt concentration the reaction was gradually retarded and finally required several hours for completion in salinities above 30 or below 5 parts per thousand.

The beneficial and stimulative value of minute amounts of copper must not, however, be construed to indicate that trade wastes contain-

ing this metal are helpful in this respect for a great amount of the metal had a poisonous effect on the larvæ and caused death in a very short time. Trade wastes of an alkaline nature are also found to be detrimental as they precipitate from the river water its normal content of copper and thus deprive the oyster of an essential element for setting and transformation into the adult stage.

Experiments with the partition type of seed-oyster collector.—Experiments carried out in Connecticut by Mr. Prytherch in cooperation with the Bluepoints Co., Connecticut Oyster Farms Co., and F. Mansfield Oyster Co., have shown conclusively that the cement-coated partition is a practical and efficient device for collecting and transplanting heavy crops of seed oysters. In Milford Harbor over 20,000,000 seed oysters were collected on approximately 5 acres of bottom by the 7,000 partitions planted there by Capt. C. E. Wheeler of the Connecticut Oyster Farms Co. On this same acreage the setting was sufficiently heavy to warrant a planting of ten times as many partitions, which would easily have collected 50,000,000 more seed oysters that were lost as a result of overcrowding and lack of room for growth. For example, it was found by actual count that from 8,000 to 12,000 spat were attached per single partition on August 20 and that by the middle of September this number had been reduced to approximately 4,000 to 6,000 as a result of overcrowding. The shells and gravel over which the partitions were planted were also totally covered with spat so that the partitions actually saved millions of seed which would otherwise have been lost.

Several of the partitions were weighed when the spat were only a few days old and also when they were 2 months old and ready to be transplanted. During this interval the weight of a single partition increased on the average from 2 to 2½ pounds, which shows that approximately 7 tons of oyster seed were collected and grown on the 7,000 partitions. Similar results were obtained by the Bluepoints Co., with a schooner load of 13,000 partitions, which were brought over from Great South Bay, Long Island, and planted in Long Island Sound off Bridgeport. There was no evidence that a set would occur in the former region; and since predictions had been issued for a heavy set in Connecticut, it was deemed advisable to move the collectors to the more promising region. On the advice of the bureau the shipment was rushed and planted just in time to catch one of the heaviest sets of oysters that has occurred in Connecticut in recent years. In New Haven Harbor the 5,000 partitions which were planted under various conditions by Howard W. Beach of the F. Mansfield Oyster Co. collected approximately 10,000,000 seed oysters in addition to those on the shells over which the partitions were planted.

The partitions used during the past summer were greatly improved by making them according to the pattern used in cardboard fillers for duck eggs. With this design the compartments were much larger and deeper and allowed greater room for growth of the oyster spat. Each partition consisted of 12 interlocking strips, 11½ by 2½ by 3½ inches, which when coated with a mixture of cement, lime, and sand, presented a total surface of approximately 690 square inches. In coating the partitions, various mixtures were tested, the most suitable being found to consist of the proportions of two sacks of

sand, one sack of cement, and one-fourth to one-half sack of slacked lime.

When the seed oysters on the partitions had reached an age of 1½ to 2 months, they were transplanted from the shallow inshore areas to the deeper waters of Long Island Sound. It was found that the partitions could be easily broken apart and the seed oysters separated by simply forcing the collector together by pressure across any two diagonally opposite corners. This required but a single operation which detached a large number of the seed and broke up the partition into 60 small squares, 2 by 3 inches. The oysters on many of these squares were kept under observation and were found as they grew larger to gradually break apart and separate as single individuals. After the partitions are broken up into squares, the seed oysters can be easily shoveled back on deck in a pile and then thrown overboard on suitable growing grounds.

PROTOZOAN PARASITE OF OYSTER GILLS

Many oysters from Milford Harbor, Conn., were found to have decidedly undersized gills with frayed, ragged edges, which indicated that they were being injured, or had recently recovered from damage, by some unknown agency. A cytological study of these specimens by Mr. Prytherch at the University of Pennsylvania showed that the gill tissue had been invaded by ciliate protozoa, which attacked the delicate, nonciliated cells lining the water tubes and epibranchial cavities. In these cells the protozoa were found to be reproducing rapidly and destroying this thin layer of tissue which separates the blood vessels of the gills from the sea water that continually passes over it. The portion of the gill in which the parasites were found is supposed to function in the oxygeneration of the blood so that injury in this region would not only affect the respiration of the oyster, but would also indirectly bring about destruction of the ciliated cells and gill filaments by disrupting their blood supply. The parasite is a ciliate protozoan of the order Heterotrichida, and varies in length from 8 to 10 microns at the time of first invasion to 15 to 25 microns when full grown. It was found to be present in the gills of spat only 1 month old and in adult oysters of various ages. In a few oysters over 50 per cent of the gill tissue had been destroyed, so it is evident that this parasite may easily interfere with the respiration, retard growth or cause death of the oyster.

CAUSES OF OYSTER MORTALITY IN VIRGINIA

During the winter of 1929–30 the oyster planters of Virginia, particularly those in Mobjack Bay and York River, suffered from some unknown cause a heavy loss of their stock, amounting to over one-half million dollars.

As a result of this high mortality of oysters and a decline of over 3,000,000 bushels in the annual production from 1904 to 1927, the State of Virginia requested the U. S. Bureau of Fisheries to undertake an investigation of this valuable sea food resource.

In response to this request a cooperative investigation was begun by H. F. Prytherch and W. H. Dumont of the Federal Government on May 12, 1930, for the purpose of determining: First, the cause of the mortality of oysters during the previous winter; and second, the most suitable means for restoring and increasing their production. In carrying out its program, the bureau has received excellent cooperation from the department and officials of the Commission of Fisheries of Virginia, from the department of biology, William and Mary College, and from the State health department. The investigators are particularly indebted to Capt. John B. Bush of the *Katie* for information regarding local conditions and assistance in the experimental work.

Though the investigation is still in progress, it was deemed advisable to issue a brief summary of the work performed and the results which have been obtained up to the present time (January 15, 1931).

Since the greatest loss of oysters occurred in Mobjack Bay and vicinity, this phase of the investigation has been concentrated chiefly in that region. A temporary field laboratory was established at Yorktown and cruises made at regular intervals with the State boat *Katie* to various stations in Mobjack Bay and York River.

Experiments were made also in the James and York Rivers for the purpose of determining a practical policy for rehabilitation of the oyster resources.

During this phase of the investigation particular attention was paid to the oxygen content of the water in Mobjack Bay as a deficiency of oxygen has been responsible for the destruction of oysters in other regions. In the lower layers of water in this bay the oxygen content varied during the summer from 1.1 parts per million to 4.9 parts per million, while at the surface it was always from 2 to 5 parts higher. The soft mud bottom was found to contain from 50 to 120 parts per million of hydrogen sulphide, which reduced the oxygen content of the water to zero whenever stirring up of the bottom occurred. Large numbers of oysters were not only partly buried in this mud, but previous to their death were subjected to the continual settling of clouds of mud upon them as extensive dredging operations were in progress.

Precipitation and river discharge in tidewater Virginia were higher than usual in October and November, 1929, so that the oyster beds received a considerable deposit of sediment, eelgrass, and debris, which would further reduce the oxygen in the lower layers of water. The high mortality of oysters in Mobjack Bay may easily have been brought about by the combined effect of the following circumstances; namely, (1) unusually heavy planting of oysters in this region, (2) deficency of oxygen supply because of overcrowding of oysters and of sedimentation, stirring, and resettling of mud bottom by dredging operations, (3) direct poisonous effect of hydrogen sulphide and other toxic products of decomposition, (4) previous weakened and diseased condition of the muscles of the oysters from causes at present under investigation.

This latter factor is perhaps of greatest fundamental importance in the recent mortality since the studies show that there existed a

pathological condition of the muscle tissue in oysters from several different localities, but that death of the oysters occurred chiefly on the areas where bottom conditions were least favorable. Since the muscle of the oyster requires a greater oxygen supply than any other tissue, it is apparent that the oysters on poor bottom would be the first to weaken and die because of an insufficient amount of oxygen for normal functioning of the muscle and closure of the shell.

EFFECT OF WASTE PULP-MILL LIQUOR ON THE OYSTERS

A study was made by Dr. A. E. Hopkins of the effect of waste liquor from a sulphite pulp mill on the Olympia oyster. Experiments carried out at the temporary laboratory established by the bureau near Olympia, Wash., demonstrated that the waste liquor was highly toxic to oysters in concentrations as low as 1 part to 2,000 parts water. All oysters treated with these solutions for a sufficient length of time either died within about 30 days, or did not remain open to feed as much of the time as did control specimens in presumably uncontaminated sea water. The death time of oysters in solutions of sulphite liquor varied in an inverse manner with the concentration. Specimens which reacted to the liquor by remaining closed a large portion of the time were able to live longer in the solutions than oysters which remained open during most of the period of treatment. In no case was new shell growth observed in oysters in liquor solutions, although control specimens showed considerable new growth. These effects were not due to acidity of the liquor for they were observed as well when neutralized liquor was employed.

Kymograph records of the shell movements of Olympia oysters at different temperatures were found to show a striking effect of changes in temperature on the relative length of time the shells remain open. Since feeding can occur only when the shells are open, the significance of these observations is obvious. In the laboratory the water showed an average diurnal fluctuation of about 2° C. between the minimum (about 6 a. m.) and the maximum (3 to 4 p. m.). At low temperatures, 4° to 7° C., this fluctuation produced a great difference in shell movements, while at higher temperatures, 14° to 17° C., the same temperature change caused almost no change. While at low temperatures a small drop in temperature causes the oyster to close, at high temperatures the same drop is almost without effect. A report on this work will be published in the near future.

Experiments have been made to determine the relative sensory effect on the oyster of certain salts which are in solution in sea water. The oyster is highly sensitive to these salts and can detect them in very dilute concentrations, as shown by the retraction of the tentacles and contraction of the adductor muscle, which closes the shells. The order of stimulating efficiency of the ions is as follows: Cations, K, NH_4, Na, Li; anions, I, Br, NO_3, Cl. A report on these observations is in press.

Field work on the investigation of oyster mortality near Shelton, Wash., conducted by H. C. McMillin was completed early in January. It was found that the death rate of oysters in Oakland Bay was very high. On the lower ground only occasional oysters were

left, while on the higher ground the living ones were very poor. No marketable oysters remained on the beds. The green-colored, clear water normally found over the oyster beds had been changed to a coffee-brown color which was quite opaque. This change took place subsequent to the beginning of operations by the pulp mill at Shelton, Wash. It was found that Oakland Bay contained about 26,000 acre-feet of water of which an average of 200 acre-feet was renewed each day by tidal action. The pulp mill operation acknowledges the dumping of 70,000 gallons of sulphite liquor into the bay beside certain wash waters. It is possible to calculate the concentration of sulphite liquor in the bay at any time from a mathematical formula taking into account the proportion of liquor to sea water, the number of acre-feet of liquor discharged into Oakland Bay by the mill per day, the number of acre-feet of new sea water brought in by tidal action each day, the volume of the bay in acre-feet, and the time in days. By this formula the equilibrium concentration may be calculated when a given amount of sulphite liquor is added each day. The discharge of 70,000 gallons per day at the mill would bring about a concentration of 1 part of liquor to 930 of water in Oakland Bay, which concentration, laboratory experiments showed, would seriously affect oysters. The State fishery inspectors show in their reports that several times as much liquor was discharged at the mill as was used in these calculations.

During June and July experiments were conducted on the spawning of the native oysters. It was found that the larvæ were discharged from the mantle cavity of the parent when they were taken into the laboratory or handled in any way, unless great precaution was used. This discharge took place regardless of the stage of development of the larvæ and suggests that seed-moving operations of the oyster growers should be completed before the oysters "come into spawn."

Efforts to rear larvæ in aerated tanks were not successful. The young lived and grew, but they maintained a symmetrical shape and did not set within the normally expected time. In the mantle cavity of the mother, development took place normally in the laboratory. Under constant temperature conditions the incubation period was reduced from 14 days to 6 days.

ANALYSIS OF OYSTER BOTTOMS

A mechanical analysis of some oyster bottoms of Georgia was made by W. H. Dumont to ascertain if there is any correlation between the grain size of the particles and the consistency of the bottom. It was found that no relation existed between the amount of clay or sand and the degree of softness. This was especially shown in two samples taken within 20 feet of each other in Georgia in March—one was a hard gray clay while the other was a soft brown mud. A mechanical analysis by the pipette method showed the grain sizes of both to be nearly identical. The only differences found were a higher organic content and faster rate of settling of the particles of the hard clay sample.

At the request of the Bureau of Fisheries the Bureau of Public Roads made several additional tests, but was unable to find any

differences between the two samples. The Petrological Laboratory of the Geological Survey examined them and found that the part designated as clay was composed mainly of diatoms, which were evenly distributed in both samples.

A further study is planned on the consistency of bottoms and the degree of hardness necessary for the planting of oysters.

CONTROL OF STARFISH ON OYSTER BEDS

A study of the biology of the starfish with the view of finding a practical method of eliminating from oyster beds this animal, which is so destructive to oysters, was made by Louise Palmer at Cold Springs Laboratory, Long Island. Oyster growers in Long Island Sound spend thousands of dollars each year in fighting this serious pest, for starfish devour countless numbers of oysters throughout their whole life history from the time the larvæ set on the shells until the mature oyster is marketed. Young starfish no larger than a pinhead eat many of the newly set oysters, termed spat, during a 24-hour period, while large starfish take several hours to open and consume the adult oyster, 2 or 3 years old. One grower in Long Island Sound kept accurate records of the amount of starfish caught on his beds in one year. In 1929, he removed 650 tons from Naragansett Bay. This not only meant a loss of hundreds of dollars in an effort to destroy these pests but an incalculable loss due to the number of oysters already destroyed.

In 1889 Doctor Meade, now of Brown University, working for the U. S. Bureau of Fisheries, studied the habits of the starfish in order to discover some angle of attack for extermination. Since that time no effort has been made to learn the natural history of starfish in different regions or to study their ecology and physiology with the purpose of control.

Since mechanical control of starfish as now practiced is expensive, time consuming, and effective only in limited areas, an attempt was made during the summers of 1929 and 1930 to find some chemical means which would be effective and practical on the beds for their eradication. Many chemicals were tried, but copper sulphate was the only substance found to be effective in minute amounts and at the same time worth practical consideration. During the past summer tests were made to determine the effectiveness of this salt on the starfish, the oyster, and other marine forms.

Large starfish were more resistant to copper sulphate than small ones. Starfish of all sizes were killed by exposure of 12 to 15 minutes to concentrations of 100 parts of copper sulphate to 1,000,000 parts of water, the larger ones requiring the longer exposure and so on until the smallest tested were killed with 4 minutes' exposure. The time of exposure is inversely proportional to the concentration, 15 seconds' exposure being sufficient for death in concentrations of 1,000 parts per million. The minute starfish are killed by concentrations of 10 parts per million but this concentration is ineffective for large starfish except for impractically long exposures.

The effect of the copper sulphate is dependent on salinity, hydrogen-ion concentration, and temperature. A chemical reaction occurs between the copper from the sulphate and the carbonate in the sea

water so that in more saline waters a greater percentage of the copper is precipitated out as insoluble carbonates and hydroxides. Less soluble copper is available for toxic action, therefore longer exposures are necessary for death in the more saline water. Higher hydrogen-ion concentration tends to release the carbonates and keep the copper in solution so that less exposure is necessary for death. As the temperature increases the toxic action increases to such a degree as to lead to the conclusion that chemical rather than physiological factors have resulted in death to the organism.

Consideration was given to the effect of copper sulphate on other marine forms, particularly the oyster. Two parts per million of copper sulphate cause the valves to close and remain so for 30 or more minutes, while strong concentrations such as 1,000 parts per million cause the oyster to remain closed for several hours. Young oysters have a greater tendency to open in the presence of copper sulphate than the older oysters and consequently are more likely to be killed. However, the danger from the poison is unimportant in comparison with the total extermination of a given crop which is probable when starfish are present.

PEARL OYSTERS IN HAWAIIAN ISLANDS

In 1928 the Territorial government of Hawaii requested that an investigation be made of the pearl-oyster beds discovered in 1927 in Pearl and Hermes Reef, a small lagoon located about 1,100 miles in a west-northwestern direction from Honolulu. Because of a lack of funds the project could not materialize until the Navy Department consented to loan a vessel for the purpose, and the Territorial government appropriated a small sum to cover part of the expense.

On July 15, 1930, Dr. Paul S. Galtsoff, in charge of the expedition, sailed aboard the U. S. S. *Whippoorwill* from Pearl Harbor, Hawaii, and arrived at Pearl and Hermes Reef on July 19, 1930. The ship was anchored outside the lagoon about 13 miles from the southeast island where headquarters were established. Pearl and Hermes Lagoon is an atoll about 18 miles long and 12 miles wide, and is partially surrounded by a narrow strip of coral reefs which embrace it on the east, south, and southwest, leaving the northern and northwestern sides unprotected. A series of islands, most of them merely sand bars, extends from the northeastern corner along the eastern and southern sides of the lagoon. The lagoon itself comprises a maze of small reefs and channels, with the depth of water varying from a few inches to 104 feet, and the reefs growing inside the lagoon are made up by a fingerlike coral "porites." The flat tops of the reefs are covered with very soft sand and old broken corals, while live corals grow on the very steep slopes of the reefs. Pearl oysters are found almost exclusively among the corals on the slopes of the reefs at a depth of from 10 to 47 feet, but below that the bottom is composed of sticky coral mud unsuitable for pearl oysters.

Inasmuch as no detailed hydrographic survey of Pearl and Hermes Reef has ever been made, considerable time was spent by the expedition in mapping the area and in determining the exact position of the islands. This part of the work has been carried out

by Lieut. M. M. Nelson, commanding officer of the U. S. S. *Whippoorwill*, who made astronomical observations and determined the longitude and latitude of several points on the islands. Three high signal towers built on the island were carried on the motor boat and placed in shallow water in the middle of the lagoon. They were supplied with platforms from which the location of pearl-oyster beds, marked by buoys, was determined by means of compass and range finder.

Biological observations consisted of the following: Sounding; taking of samples of bottom and water; temperature readings (top and bottom); and determinations of the alkalinity of the water, of its transparency, and of its food content. For the examination of pearl-oyster beds three divers were employed, who were directed to swim and dive for a period of time varying from half an hour to an hour and a half. Because of the irregular distribution of pearl-oyster beds the total number of the present oyster population of the lagoon could not be determined. However, from the data obtained during the investigation it is possible to determine the relative abundance of oysters; that is, the number of oysters found by the average diver during a given period of time.

Biological observations just described were carried out at 70 stations uniformly distributed over the whole area of the lagoon, and from an anaylsis of the data the following conclusions can be drawn:

Pearl oysters grow at a depth of from 10 to 47 feet, attached almost exclusively to live corals. The average weight of the adult oyster is about 2 pounds, and the maximum weight is 7 pounds, but at present those weighing over 3 pounds are rather scarce. All the oyster reefs examined in the course of the investigation show signs of depletion. On most of them, 3 divers were able to find in one hour only 3 or 4 oysters.

One-year-old oysters were almost entirely absent. This fact indicates that either oysters failed to spawn and set in 1929 or that last year's crop was destroyed by the fishermen. Because small oysters have a tendency to attach themselves to the shells of the adult ones the second explanation seems to be very probable.

Pearl oysters spawn and set in Pearl and Hermes Lagoon in July and August. There are two factors which are essential for a successful spawning: High temperature of the water (27° C.) and abundance of adult oysters on the reef. The latter factor is as important as the first one. When oysters are scarce and single individuals are scattered over the large area, the two sexes fail to stimulate each other and chances for spawning and fertilization of their eggs are very small. Thus, when because of overfishing the number of the adult oysters on the reef is reduced to a certain low limit, the oysters fail to spawn and their propagation ceases. The evidence supporting this statement is found in the fact that no young oysters (spat) were found on single individuals taken from badly depleted reefs, whereas on the reefs that were not so badly overfished the spat was abundant.

Pearl oysters of Pearl and Hermes Reef produce valuable shells (mother-of-pearl) and bear large numbers of pearls. It has been estimated that since 1927, when pearl beds were discovered, not less than 100 tons of shells (about 106,000 oysters) were taken from the

reef. There is no doubt that without protection the beds will be completely wiped out in a short time.

The expedition brought back 310 live pearl oysters which were planted in Kaneohe Bay near Honolulu. It is hoped that these oysters will establish themselves in the new environment, which is suitable for their growth and propagation, and will form a nucleus of the first American pearl-oyster farm.

With the view toward conservation of the only known pearl oysters in the United States the Governor of the Territory of Hawaii has issued an order forbidding for an indefinite period of time the taking of pearl oysters from any locality within the jurisdiction of the Territorial government.

INVESTIGATIONS OF MUSSELS AND POLLUTION IN INTERIOR WATERS

The Columbia field unit, with a working staff of 11 under the direction of Dr. M. M. Ellis, is housed in a suite of eight rooms in the new section of the Medical Building of the University of Missouri. These rooms have been especially equipped by the University of Missouri to meet the needs of fishery research, and the unit is recognized by the University of Missouri as an adjunct to its graduate school.

FRESH-WATER MUSSELS

Glochidia and breeding stock.—Through the cooperation of the button manufacturers and various State officials over 6,000 gravid female mussels were examined by this unit during the past year and the condition of the glochidia studied with reference to disease, stream pollution, and utilization for propagation purposes. This work involved the handling of several thousand additional mussels, as well, for correlations with age, locality, and general condition.

Few glochidia suitable for propagation work were found, and the effects of stream pollution on gravid mussels were discovered to be far-reaching and serious, rather generally throughout the Mississippi drainage. Two conditions in particular seem deserving of special mention, viz, bacterial infection and chemical poisoning.

Many marsupia, particularly from mussels collected in the Mississippi and tributaries below or near large cities, were found to have black masses filling units of the marsupium normally occupied by conglutinates of glochidia. When the masses were opened they were found to contain dead and disintegrating glochidia and to be heavily infected with bacteria. Bacteriological studies of these masses showed that in addition to the usual bacterial flora to be expected in any decomposing mass of tissue, one particular organism, similar in many respects to the well-known *Bacillus proteus*, was recovered as the principal organism from this mass. Experimental work is now in progress to determine whether this particular bacillus is of primary or secondary importance in the production of these lesions in the brood pouches of mussels. It has been noted that the glochidia in conglutinates adjacent to these black masses are less reactive than normal glochidia, often being entirely unreactive, and that this black mass spreads through the marsupium once the condition appears in a mussel, thus sterilizing the mussel as far as natural reproduction is concerned. These bacteriological studies are being continued in connection with the other pollution studies mentioned below.

Tests on the closing reactions and responses to nutrient fluids have shown that the glochidia from mussels living in polluted waters are on the whole much less reactive than glochidia from mussels held in pure water. Several specific substances have been found which can contribute to this reduction in activity of the glochidia. The resulting reduction in activity of the glochidia by these pollution substances amounts practically to the sterilization of the mussel, as the glochidia are often found unable to close, which would, of course, prevent any natural replacement of these mussels as the glochidia would not be able to attach themselves to fishes.

Condition of fresh-water mussels and of mussel beds.—Detailed physiological studies of the blood and internal organs of over 1,000 fresh-water mussels were made to ascertain the normal conditions in healthy mussels. These data are now being used to determine the effects of pollution on fresh-water mussels.

The adult fresh-water mussel has been found to be very sensitive to a variety of substances which may be present in fresh water, in fact contrary to the view commonly held, these studies have shown that many species of fresh-water mussels are fundamentally clean-water animals and that their ability to adjust themselves to conditions of stream pollution is sharply limited. Many substances placed in solution in the water surrounding the mussels were soon recovered in the blood of the mussels, and the average fresh-water mussel was found to have little ability to prevent the entry of toxic and other undesirable substances into the blood, but that it depends upon temporary closure of the shell to keep out noxious substances. Consequently these mussels are unable to withstand the conditions in many streams where contaminating substances are constantly poured into the water, as the mussels can not remain closed indefinitely.

Purification of water by mussels.—An elaborate series of experiments has been in progress since early spring dealing with the question of fresh-water mussels as water purifiers. The removal of silt, organic débris, and other materials, under various conditions by these animals is being checked.

Two special pieces of apparatus have been evolved for this work: (1) A device which maintains a constant condition of turbidity in the aquarium under observation so that mussels may be studied for long periods of time under conditions similar to those in rivers and streams just after heavy rains, when the water contains large amounts of silt and clay in suspension; and (2) an apparatus by means of which very minute quantities of suspended matter in the water may be measured, thus making quantitative studies possible.

The activities of individual mussels have been recorded continuously for long periods of time (in many cases in excess of 1,000 hours). From these observations it has been found that the efficiency of a fresh-water mussel as a water clearer has been greatly overestimated in the popular accounts of these animals. Many mussels were found to remain closed for more than 50 per cent of the time, and they can not purify water during the time they are closed. Again the mussels in an effort to protect themselves close frequently when pollution materials are added to the water so that during the time when the purification of water is most desired, the mussels are most apt to be closed.

Concerning the removal of silt it was found that such silt as is taken out of the water by the fresh-water mussels is returned to the stream in the form of small globular masses in which the slit is bound together with mucus secreted by the mussel, and that these masses subsequently disintegrate so that the silt has been removed only temporarily from the stream.

The bacterial studies carried along with these activity experiments have shown that in material taken into the alimentary canal of the mussels the bacteria may pass through the mussel unaffected, to be returned to river water in less than five hours, so that the reduction of bacteria in river water by mussels not only does not take place but in many experiments it was found that the number of bacteria in the water actually increased after the mussel was placed in the water.

SURVEY OF UPPER MISSISSIPPI RIVER

From June 29 to September 6, inclusive, the personnel of the Columbia unit was engaged in a survey of the Mississippi River from Quincy, Ill., to Point au Sable, Minn., in Lake Pepin, conducted jointly by the Corps of Engineers, U. S. Army, and the U. S. Bureau of Fisheries to consider the probable effects of the changes in the Mississippi River incident to construction of the proposed 9-foot channel. This survey gave particular attention to the changes which have been produced in the Mississippi River and its fauna and flora by the Keokuk Dam and by the various wing dams which have been constructed as aids to navigation.

U. S. Engineer quarterboat *No. 348* (Fig. 9) was placed at the disposal of the U. S. Bureau of Fisheries, and was used throughout the summer as a floating laboratory. Ample equipment was taken aboard to provide for the chemical, physical, bacteriological, and biological work in the field, and the preserved material was forwarded to the Columbia laboratory for final study.

Fresh-water mussels, fish, and fish food were collected and studied, and detailed chemical and physiological analyses of both the water and the river bottom were made throughout the summer. Individual observations on over 6,500 fresh-water mussels above were made during the course of this work and large quantities of other material taken.

In the main the results of this work may be summarized as follows:

There are three major factors at work at present changing the fisheries situation in the Mississippi and each of these combines with the other two in accelerating the change now going forward.

(*a*) Construction and reclamation of flooded land by dikes and pumping stations have reduced the lateral shore zones of shallow water in many places along the Mississippi to such an extent that suitable spawning grounds and shallow waters in which young fish may thrive are practically wanting. With the loss of these lateral zones of shallow water the production of plankton, the basic fish food, has been greatly reduced in certain parts of the river.

(*b*) Municipal and industrial wastes, sewage and factory run-offs in particular, have so polluted many sections of the river that only those animals capable of existing under very adverse conditions are able to maintain themselves. This problem is acute in many places

and the bacterial counts from water at considerable distances from these sources of pollution were extremely high.

(*c*) The enormous quantities of erosion silt entering the Mississippi have produced a condition of supersaturation so that any slowing of the water either by man-made or by natural obstructions results in a rapid deposition of large quantities of silt. This silt first of all is smothering out all sorts of bottom life by simply burying the bottom animals under a layer of soft ooze, varying from a few inches to 7 or 8 feet in thickness, in which they are unable to live. Besides this factor, and it in itself is serious, this silt carries down with it quantities of undestroyed organic material put into the river by the sewage of the larger cities. This organic matter is buried in a thick colloidal suspension and the decomposition of the organic fraction proceeds more slowly than if the waste were in the moving

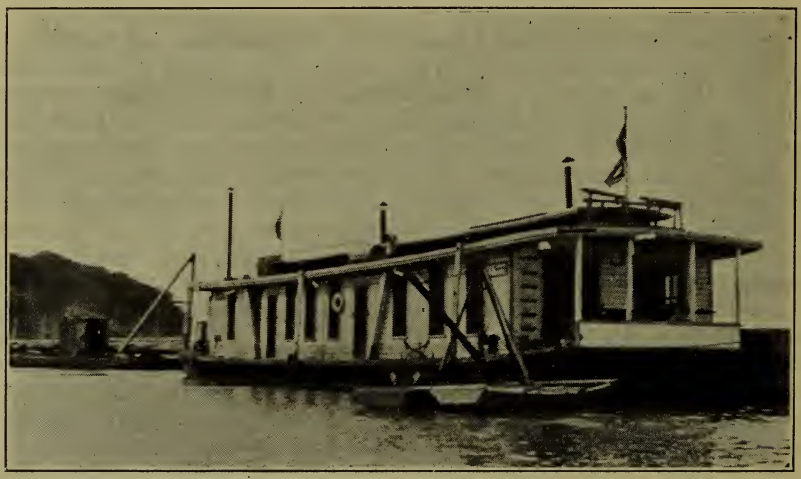

FIGURE 9.—U. S. Engineers' Quarterboat *No. 348,* used as a floating laboratory in a limnological study of the upper Mississippi River

stream. As a result the oxygen demand of water rises rapidly and the oxygen saturation falls in those portions of the river where the water is slowed down and the silt deposited. Large volumes of methane, and various sulphurous gases were found rising from some of these silt deposits, and the fauna reduced to bloodworms and other forms indicative of low oxygen conditions.

The silt situation was found very acute, as practically all the river bottom is receiving a deposit of this silt-sewage mixture except the swifter portions of the channel proper. Control of the silt and sewage situations is badly needed regardless of the construction of dams or levees, as these merely make more immediately acute conditions which will doom the desirable fauna of the river unless checked soon. Large areas of dead mussels which had been killed by the silt-sewage layer were found at many stations and the changes in fish fauna from the bass-crappie group to the carp-sucker group were very evident in the localities where these conditions of pollution were very severe.

The replacement of the valuable fresh-water mussels, such as the yellow sand shell, the pigtoe, the niggerhead, and the mucket, by

noncommercial species was very evident in all sections of the river studied. Paper shells and floaters, worthless species as far as button manufacturers are concerned, were the only species found to be replacing themselves under the new conditions. Young of the commercial species were rarely found, while large numbers of the young floaters and paper shells were collected in many places, particularly behind wing dams, log-jams, and other obstructions where the sand shells and other valuable species had been killed out by the silt deposits.

POLLUTION STUDIES

In connection with the Mississippi River survey, the glochidia studies, and certain industrial problems, the effects of stream pollution on fish, fish food, and fresh-water mussels have been investigated both in the field and in the laboratory. Throughout the summer and fall the bacteriologist of the unit has followed the bacterial flora in all of these studies, and the chemical, physiological, and bacteriological aspects have been investigated by other members of the staff. Work has been carried on and is in progress along the following lines:

(*a*) General and municipal sewage pollution; (*b*) industrial pollution, particularly sulphur, acid pollution, and arsenic; (*c*) erosion silt; and (*d*) oxygen saturation.

In the experimental studies on pollution the oxygen limits as influenced by these various pollution factors have been given particular attention. Fresh-water mussels, for example, show a marked reduction in their vital activities when the oxygen saturation is reduced to below 25 per cent, and their reactions to the specific substances polluting the water are modified by the state of activity as produced by the oxygen saturation, thus creating a physiological vicious cycle.

BOTTOM STUDIES

Experimental studies both in the laboratory and on selected areas in the river concerning the physiological, chemical, and biological factors contributing to the survival or elimination of juvenile mussels have been made with a view to obtaining data on suitable grounds for the planting of young mussels. Much progress has been made in this field where there are few previous observations.

HOLDING AND FEEDING OF ADULT FRESH-WATER MUSSELS

In view of the rapid decline in the valuable commercial mussels in so many parts of the Mississippi drainage and the attendant difficulties in securing adequate breeding stock and good glochidia for the propagation work, series of adult mussels have been held throughout the year in tank aquaria to determine whether it is feasible to hold adult mussels in numbers and thus select proper breeding stock. As a corollary of this work the conditions of the animals as shown by blood and other biochemical studies have been followed. One of these biochemical studies has demonstrated that mussels in good condition when first taken from the river have a large reserve of stored food in the form of glycogen, and that if kept in water containing practically no mussel food this reserve of glycogen is steadily used up.

The stored glycogen seems adequate, however, in the case of healthy mussels to carry them through several months of starvation. When fed, the glycogen content of the mussels rises rapidly to the former level. It does seem feasible from these experiments to hold mussels in water containing little mussel food and to select breeding stock from the best animals surviving. Application of these findings are to be tested on a large scale through the coming season.

APPROPRIATIONS

It often has been said that the financial support provided by Congress for the scientific work of the bureau may be taken as a measure of public approval of the results of the research program. If such be the case, we may view with considerable satisfaction the record of appropriation during the past few years. Up to the period of recovery from the World War, Federal appropriations for scientific research by the bureau increased at a fairly constant rate, along with the general development of the country and the expanding functions of government. From 1918 to 1924 followed a period of retrenchment in appropriations, but from that year until the present, scientific inquiry's funds have shown a steady increase. Funds expended by the division of scientific inquiry for fishery research in the United States, given in round numbers, for the various years are as follows: For 1924, $91,000; 1925, $118,000; 1926, $129,000; 1927, $144,000; 1928, $175,000; 1929, $198,000; 1930, $198,000; and 1931, $262,000. These figures represent the combined appropriations from various accounts, except funds spent for vessel operations in connection with scientific work. In addition to the totals shown, in the fiscal year 1929, $20,000, and in 1931, $179,000, were appropriated for building improvements at the biological laboratories or for the erection of new ones.

For the fiscal year 1931 these funds were allotted in the various sections of the country as follows: For fishery investigations in the Atlantic and Gulf coast areas, 30 per cent; for the Great Lakes and interior lakes, 9 per cent; for the Pacific coast, 16 per cent; for investigations in the interest of fish culture throughout the country, 17 per cent; for shellfish investigations, including oyster-cultural studies, mussel propagation and pollution studies, and shrimp investigations, 19 per cent; for studies on the conservation of fish by means of screens and ladders, 9 per cent. With authorization for continued increases in appropriations for scientific work provided by the act of May 21, 1930, it is anticipated that the orderly program of investigation designed to make more effective the conservation of our marine and inland fisheries will be carried out, and that attention can be given to other sections of the country and to fisheries that are at present neglected. The only weakness of this program of expansion lies in the failure to provide for increased vessels' operations as was mentioned above. On the Atlantic coast particularly fishery investigations are hampered by lack of adequate vessel facilities, and it is hoped that the early rectifying of this lack will permit the complete realization of a well-rounded program of fishery investigation.

○